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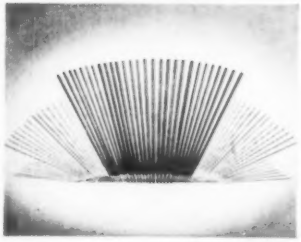

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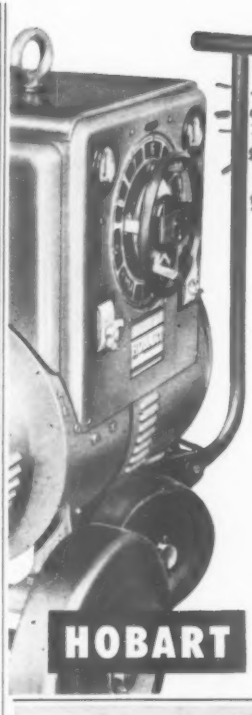

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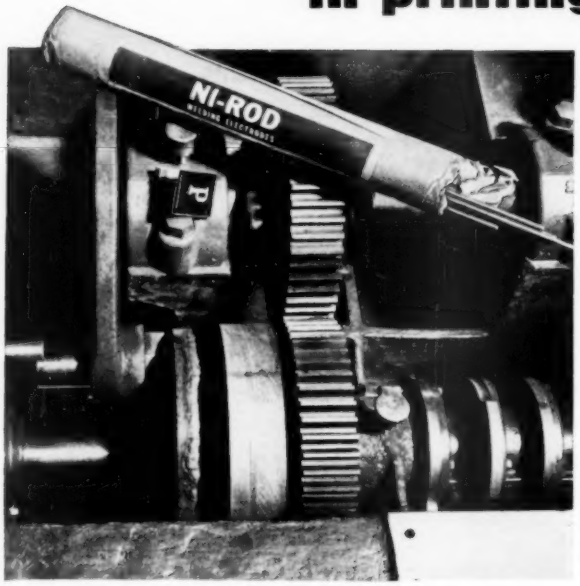

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cover: Operator roping a 12-inch screw collar under approximately 500 pounds pressure on a 12-inch line. Courtesy The Lincoln Electric Company

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Specific heat (calculated), calories per deg. C.	0.110	0.1124
Mean coefficient of thermal expansion per deg. F.	0.0000084 (from 32 deg. to 1463 deg.)	0.0000082 (from 32 deg. to 1652 deg.)
Magnetic properties	Somewhat magnetic; much less than steel.	Strongly magnetic; somewhat less than steel.
Mechanical Properties		
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The WELDING JOURNAL

volume 28 MAY 1949 number 5

Welding Nomenclature and Definitions

A discussion of some of the basic concepts involved in the formulation of the new "Standard Welding Terms and Their Definitions" which have just been approved. This article presents some of the reasoning leading to the formulation of these terms.

by W. L. Warner

THE considerable expansion of welding due to industrial development and application of welding processes during the past decade has enriched American technical literature with many picturesque terms and esoteric phrases utilized to express new ideas and concepts. Many of these terms have been employed to indicate modifications of older concepts for the purpose of establishing a particular viewpoint or to describe the value of a new development. Unfortunately, lack of uniformity and coherence frequently result from such usage.

When attempting to prepare codes or specifications covering the application of welding processes it is often necessary to include detailed explanations and directions in order to clearly establish the intent of the requirements which are prescribed. Such a necessity is not only very burdensome to both writer and reader but also, because of its nonstandard form and interpretation, often fails to accomplish its objective. Then too, one of the most frequently criticized features of welding contracts, specifications and reports is the verbiage utilized in their preparation. The availability of an adequate reference standard on classification of welding processes, welding nomenclature and definitions would simplify this problem of expression to a considerable extent.

The A.W.S. Committee on Definitions and Chart, within whose sphere of activity such standardization work should be carried on, has been actively engaged with this problem for over four years. It should be recognized that a project of this sort is not only arduous but time-consuming, involving much long, detailed discussion and argument regarding fundamental concepts and individual viewpoints, before general agreement can be obtained among all interests involved. The problems confronting this Committee have been such that their satisfactory solutions have assumed considerable fundamental importance with reference to standardization of industrial practices and the establishment of welding standards, specifications and codes sponsored by the AMERICAN WELDING SOCIETY.

It is the writer's privilege to have been associated with the work of the Committee on this project and to attempt to explain the reasoning behind some of the fundamental concepts and principles established by the Committee in its revision of the 1942 Nomenclature Standard. The A.W.S. Committee on Definitions and Chart has given much time and thought to this problem of revision.

W. L. Warner is at the Watertown Arsenal, Watertown, Mass.

NOTE: The standard itself will be available shortly in bulletin form. These terms and definitions will also be included as Chapter 1 of the Third Edition of the *Welding Handbook*.

A.W.S. COMMITTEE ON DEFINITIONS AND CHART

R. W. Clark, *Chairman*, General Electric Co.; S. A. Greenberg, *Secretary*, AMERICAN WELDING SOCIETY; L. C. Bibber, Carnegie-Illinois Steel Corp.; Bureau of Ships,* Navy Department, Washington, D. C.; O. R. Carpenter, Babcock & Wilcox Co.; J. H. Deppeler, Consulting Engineer; T. R. Higgins, Amer. Inst. of Steel Constr.; H. O. Hill, Bethlehem Steel Co.; R. T. Jones, Handy & Harman; W. E. McKenzie, U. S. Naval Gun Factory; N. W. Morgan, U. S. Public Roads Administration; W. G. Morgan, Noblitt Sparks Industries, Inc.; C. W. Obert, Linde Air Products Co.; W. W. Reddie, Westinghouse Electric Corp.; F. C. Saacke, Air Reduction Sales Co.; C. B. Voldrich, Battelle Memorial Inst.; J. J. Vreeland, Chase Brass & Copper Co.;

* Represented by C. A. Loomis and J. R. McClendon, Welding & Materials Section.

Watertown Arsenal,† Ord. Dept., Department of the Army and J. L. Wilson, American Bureau of Shipping.

The Resistance Welding Terms with definitions which are included were supplied by the A.W.S. Resistance Welding Committee. Likewise the Brazing Terms with definitions were supplied by the A.W.S. Brazing Committee.

In outlining a program for the project of revision the Committee planned the work in four phases:

1. Formulation of a Master Chart of Welding Processes.
2. Defining terminology used in Master Chart.
3. Formulation of Process Charts for distinguishing between processes listed in Master Chart.
4. Defining welding terms used in the application of welding processes.

This arrangement of program was decided upon primarily because it was considered that the Master Chart with its accompanying Process Charts, which show process classification and significant operating characteristics in some detail, forms a sort of skeleton or framework for the proposed revision of the nomenclature standard. In effect these charts may be considered to serve also as a guide to keep one's thinking straight when contemplating the whole problem of welding terminology and definitions in view of the rather complex relationships existing between interpretations of various allied terms used in welding.

THE MASTER CHART OF WELDING PROCESSES AND PROCESS CHARTS

A suitable Master Chart should be logical and consistent in form and arrangement. It should be adequate in content. Its classification system should be applicable in a practical manner. The Master Chart should include all known welding processes which have been or are being used in production and its classification system should provide a mechanism by which the results of future development can be incorporated when desired without elaborate rearrangement of the system.

It was recognized also that, before formulation of a Master Chart could be attempted, there were certain basic concepts to be established not only as a guide for the thinking of the Committee but also for the information of those who may be interested in or concerned with later use of the charts for any purpose. The following concepts were established by the Committee in formulating the Master Chart together with the terminology used thereon:

1. Concept of "What is a weld?"
2. Concept of "What is a braze?"
3. Concept of "What is a welding process?"
4. Concept of "What is braze-welding?"
5. Is a weld a "coalescence" or a "consolidation"?
6. What is the distinction between "process," "method" and "procedure"?
7. Basis of Grouping of Welding Processes
8. Format of Definitions of Processes
9. Characteristics of Processes in Process Charts

† Represented by W. L. Warner.

It is desired to briefly discuss each of these concepts but, before doing so, it is essential to point out that the subject of "soldering" has been intentionally excluded from this nomenclature revision. This has been done because the Committee's recognized field of activity covers only "welding" and "brazing." Also, the temperature limit of 800° F. which has been established to distinguish "brazing" from "soldering" has been arbitrarily established based upon general agreement for classification purposes by the Committee. It is not intended herein to argue the reasons for or against this selection.

1. Concept of "What Is a Weld?"

In establishing this fundamental concept the Committee considers that the following elements are essential to a "weld":

(*a*) A joining of metal parts occurs over a certain localized area of the parts.
(*b*) A filler metal may or may not be used.
(*c*) Heat with or without pressure is used.
(*d*) A continuity of solid metal parts results.

While it is recognized that a solid metal joining may be accomplished, in the case of several soft pure metals, by pressure without heating, all practical industrial applications of welding processes involve the use of either heating only or the combined use of heating and pressure. Therefore, it is considered that the basic concept of a weld is satisfactorily expressed by the following definition for a "weld" established by the Committee:

Weld—A localized coalescence of metals wherein coalescence is produced by heating to suitable temperatures, with or without the application of pressure, and with or without the use of filler metal. The filler metal either has a melting point approximately the same as the base metal or has a melting point below that of the base metals but above 800° F.

2. Concept of "What Is a Braze?"

In establishing this fundamental concept the Committee considers that a "braze" is a very special form of "weld" in which the following elements are essential:

(*a*) The surfaces to be joined are fitted very closely together.
(*b*) The filler metal used is a nonferrous metal.
(*c*) The filler metal has a melting point above 800° F. but below that of the base metal which it joins together.
(*d*) The filler metal is distributed in the joint by capillary attraction.

Therefore, it is considered that the basic concept of a braze is satisfactorily expressed by the following definition for a "braze" established by the Committee:

Braze—A weld wherein coalescence is produced by

heating to suitable temperatures above 800° F. and by using a nonferrous filler metal having a melting point below that of the base metals. The filler metal is distributed between the closely fitted surfaces of the joint by capillary attraction.

3. *Concept of "What Is a Welding Process?"*

In establishing this fundamental concept the Committee considers that any metal-joining process, the use of which results in a weld, should be regarded as a "welding process." Therefore, it is considered that the basic concept of a welding process is satisfactorily expressed by the following definition established by the Committee:

Welding Process—A metal joining process wherein coalescence is produced by heating to suitable temperatures, with or without the application of pressure, and with or without the use of filler metal.

4. *Concept of "What Is Braze-Welding?"*

In establishing this fundamental concept the Committee has in mind that type of metal joining which results from applying a welding process using a nonferrous filler metal for ferrous base metals, as is done in brazing, but the joint surfaces are not closely fitted together as they are when the joint is to be brazed and capillary attraction is not a factor in the distribution of the filler metal in the joint. In such cases one performs the actions of welding and ends up with a joint which has all the external appearances of a welded joint. The term "braze-welding" is considered applicable to the welding methods which produce this sort of a joint.

Accordingly, the Committee regards the following elements as essential to "braze-welding":

(*a*) A joining of metal parts occurs over a certain localized area of the parts.
(*b*) A nonferrous filler metal is used in the joining.
(*c*) The surfaces to be joined are not fitted closely together.
(*d*) The filler metal has a melting point above 800° F. but below that of the base metals which it joins together.
(*e*) The filler metal is not distributed in the joint by capillary attraction.

Therefore, it is considered that the basic concept of braze-welding is satisfactorily expressed by the definition for "braze-welding" established by the Committee as follows:

Braze-Welding—A method of welding whereby a groove, fillet, plug or slot weld is made using a nonferrous filler metal having a melting point below that of the base metals but above 800° F. The filler metal is not distributed in the joint by capillary attraction.

The Committee has further considered it to be very undesirable that "braze-welding" be given the status of a group of processes in the Master Chart on a par with Arc Welding, Gas Welding, Resistance Welding and Brazing since classifying it in that manner would necessitate the formulation of a new group of symbols, joint designs and engineering data for its use by the design engineer. It is rather deemed to be a method using these processes. Accordingly, the various braze-welding methods are indicated in the Process Charts under the respective applicable welding processes.

5. *Is a Weld a "Coalescence" or a "Consolidation?"*

The basic concept that a weld is a "coalescence" rather than a "consolidation" has been established by the Committee after careful study and consideration. Webster's Dictionary defines "coalescence" as a "growing together" or "growth into one body," whereas "consolidation" is defined as "making solid" or "compressing into a compact mass." It is considered, therefore, that "consolidation" has a broader interpretation than "coalescence" in that the former could include joining by using members external to the joint such as by bolting, riveting, nailing or strapping. Also the term "consolidation" appears always to involve some element of "force." This element of "force" is not suggested by the term "coalescence." Therefore, the term "coalescence" is regarded as more applicable generally to all types of welding processes than is the term "consolidation" which might apply primarily to those welding processes wherein external "force" is an essential element of the process.

Accordingly, all welding process definitions established by the Committee define a "coalescence" instead of a "consolidation" of metals.

6. *What Is the Distinction Between "Process," "Method" and "Procedure"?*

For the purpose of establishing suitable terminology and arrangement of the Master Chart and Process Charts the Commitee has considered it very desirable to attempt to distinguish between a "process," a "method" and a "procedure." This distinction is neither simple nor easy to accomplish and it must be regarded with some degree of tolerance by the users of the charts and of the terminology which applies.

By reference to Webster's Dictionary the Committee has established the following interpretations:

Process—A distinctive progressive action, or series of acts, involved in the course of producing a basic type of result.
Method—An orderly arrangement, or definite system, of proceeding in a certain manner to accomplish a particular type of result.
Procedure—The detailed elements (with prescribed values or ranges of values) of a Process or Method used to produce a specific result.

For example, with any welding process, distinguished as such by method of heating, type of filler metal, type of shielding or other basic factors of operation there may

be several methods of applying the process to obtain a weld. Then each method may be applied by using several procedures in each of which specific values for the various factors of operation are prescribed. The Committee has endeavored to follow this line of reasoning in preparing the Master Chart of Welding Processes and the Process Charts.

7. *Basis of Grouping of Welding Processes*

The Committee has considered the "means of heating for welding" as of primary interest in the grouping of welding processes together with the "influence of capillary attraction in effecting distribution of filler metal" in the joint. This factor of capillary attraction distinguishes those welding processes grouped under "Brazing" from those welding processes grouped under "Forge Welding," "Thermit Welding," "Flow Welding," "Gas Welding," "Arc Welding," "Resistance Welding" and "Induction Welding." The distinguishing feature of these latter groups of welding processes is "means of heating for welding." This system of process grouping is essentially the same as that used in the 1942 Nomenclature Standard except that there is no grouping according to the use or nonuse of pressure.

This omission of the "pressure" and "nonpressure" designations for process grouping in the Master Chart is the deliberate intent of the Committee because of the thought that the use or nonuse of pressure is sometimes taken to refer to the service application for the welded joint. Instead, this factor of pressure is shown as an element of operation of applicable welding processes in the Process Charts.

Since fusion is considered to be involved in certain welding processes other than arc or gas welding, "Fusion Welding" is not recognized as a group in the Master Chart. Also the type of current used in Arc and Resistance Welding Processes and whether "consumable" or "nonconsumable" electrodes are used in arc welding are not shown by the Master Chart. These items are considered to be characteristics more properly involved in distinguishing between processes and methods of welding and are therefore shown by the Process Charts.

8. *Format of Definitions of Processes*

In defining the processes which are included in the Master Chart the Committee has endeavored to make each definition as complete as possible so that it will in fact "stand alone by itself" without reference to other definitions. For completeness and clarity some definitions have been accomplished by using more than one statement but in most instances a uniform pattern of wording and arrangement has been followed

The Committee has purposely formulated these definitions from the operational instead of the metallurgical viewpoint. Thus the definitions of processes prescribe the significant elements of operation involved instead of the significant metallurgical characteristics of the "coalescence" resulting from the welding operation.

9. *Characteristics of Processes in Process Charts*

The Process Charts are intended to be supplementary to the Master Chart. They have been prepared to indicate the significant factors involved in the use of each of the welding processes included in the Master Chart. These charts are not intended as process application or procedure charts since specific values are not prescribed for the characteristics listed.

The Commitee has established the following interpretations for the Process Characteristics shown on the Process Charts:

1. *Type of Current.* The nature of the electric current used in producing the heating at the location of the weld.
2. *Source of Current.* The equipment which supplies the welding current.
3. *Polarity.* The polarity of the electrodes in a direct-current arc-welding circuit.
4. *Source of Heat.* The means by which the welding heat is generated.
5. *Heating Agent.* The manner or means by which the welding heat is applied to the work.
6. *Control of Time of Heating.* The manner or means of controlling the time of heating for welding, exclusive of preheating.
7. *Duration of Heating.* The length of time of heating required to make a weld, exclusive of preheating.
8. *Number of Heating Agents.* The number of heating agents used in making a weld, exclusive of preheating.
9. *Temperature of Base Metal.* The temperature of the base-metal surface where and when coalescence occurs.
10. *Degree of Shielding.* The degree to which air is intentionally excluded from the immediate vicinity of the coalescence being accomplished during welding.
11. *Type of Shielding.* The physical nature of the shielding agent.
12. *Shielding Medium.* The specific agent by which shielding is effected.
13. *Number of Electrodes.* The number of electrodes per heating agent used in making a weld.
14. *Type of Electrode.* The character of the electrode or electrodes with reference to whether it or they supply filler metal for making a weld.
15. *Form of Electrode.* The shape of electrodes used in making a weld and in some cases the material of the electrodes used.
16. *Use Source of Filler Metal.* Whether filler metal is used in making a weld and in some cases the source of the filler metal used.
17. *Flux.* Whether flux is used in making a weld and in some cases the source of the flux used.
18. *Pressure.* Whether pressure is used in making a weld.

19. *Source of Pressure.* The method or the agent by which pressure is applied in making a weld.
20. *Application of Pressure.* The uniformity or the variations in pressure applied during the making of a weld.
21. *Time of Application of Pressure.* The time when pressure is applied with respect to the heating cycle used in making a weld.
22. *Filler Metal Feed.* The manner in which filler metal is added during the making of a weld.
23. *Advance Along the Joint.* The advance of the welding operation along the joint with reference to whether accomplished by manual or by automatic means.
24. *Completion of Joint.* Whether the joint is completed progressively or simultaneously.

The Committee considers that Source of Heat is primarily concerned with heat generation while Heating Agent is primarily concerned with how the heat is applied to the work in welding. In both Control of Time of Heating and Duration of Heating the Committee excludes preheating and postheating and includes only the heating used during the act of welding. Shielding is indicated for those processes where it is intentionally provided during the welding operation and the amount of shielding is indicated qualitatively. There is no intent to indicate the amount of shielding quantitatively. The type of shielding is considered to be either gaseous, liquid or solid.

The use or nonuse of pressure during the making of a weld is indicated under Pressure irrespective of whether or not pressure is required to produce coalescence. The Committee intends that Pressure be associated with the making of the weld instead of with the application of the weld in service.

DEFINITIONS OF WELDING TERMS

It is recognized that the results of the Committee activity may not be entirely satisfactory to everyone concerned and it should be understood that Committee decisions usually represent a majority agreement. In formulating the definitions the Committee has been most careful to consider all shades of interpretation presented by differences of opinion. It has endeavored to determine "What is usually intended by the context with which the term is used?" The discussion which follows attempts to explain the reasoning upon which the Committee has based the definitions for some of the more controversial terms encountered in the field of welding.

Electrode

In applying the interpretation of "electrode" given by Webster's Dictionary the Committee has established the following interpretation of "electric source":

Arc Welding—That portion of the welding circuit involved which is external to the welding arc.

Resistance Welding—That portion of the welding circuit involved which is external to the work.

It is recognized that various types and forms of "electrode" are used primarily in those welding processes which utilize electricity for the required heating. Arc-welding electrodes may be of carbon or metal and the metal electrodes may be either the filler metal or nonfiller metal type. Resistance welding electrodes are usually of metal and of the nonfiller metal type. They are relatively massive in section since they must carry heavy currents without melting and heavy pressures without appreciable deformation.

Accordingly, the Committee has established the following nomenclature with their respective definitions:

Carbon Electrode—A nonfiller metal electrode, used in arc welding, consisting of a carbon or graphite rod.

Metal Electrode—A filler or nonfiller metal electrode, used in arc welding, consisting of a metal wire, with or without a covering or coating.

Bare Electrode—A filler metal electrode, used in arc welding, consisting of a metal wire with no coating other than that incidental to the drawing of the wire.

Covered Electrode—A filler metal electrode, used in arc welding, consisting of a metal core wire with a relatively thick covering which provides protection for the molten metal from the atmosphere, improves the properties of the weld metal and stabilizes the arc.

Composite Electrode—A filler metal electrode, used in arc welding, consisting of more than one metal component combined mechanically. It may or may not include materials which protect the molten metal from the atmosphere, improve the properties of the weld metal and stabilize the arc.

Lightly Coated Electrode—A filler metal electrode, used in arc welding, consisting of a metal wire with a light coating applied subsequent to the drawing operation, primarily for stabilizing the arc.

Tungsten Electrode—A nonfiller metal electrode, used in arc welding, consisting of a tungsten wire.

Resistance Welding Electrode—See Electrode

Electrode—

Arc-Welding—See Bare Electrode, Carbon Electrode, Metal Electrode, etc.

Resistance-Welding—The part or parts of a resistance welding machine through which the welding current and, in most cases, pressure are applied directly to the work. The electrode may be in the form of a rotating wheel, rotating roll, bar, cylinder, plate, clamp, chuck or modification thereof.

Automatic, Machine and Manual Welding and Cutting

The following interpretations are indicated by Webster's Dictionary:

Automatic—having a self-acting or self-regulating mechanism that performs a required act at a predetermined point in an operation.

Machine—mechanism serving to transmit and modify force and motion so as to do some kind of work.

Manual—Done, made, operated by or used with the hand or hands.

The Committee has recognized the basic significance of these interpretations in formulating definitions for the automatic, machine and manual welding and cutting processes. In addition, the Committee has included in the definitions the degree to which the welding or cutting operation is performed under the observation and control of the operator. In any case the loading or unloading of the work is considered to be incidental.

Accordingly, the Committee has established the following nomenclature with their respective definitions:

Automatic Oxygen Cutting—Oxygen cutting with equipment which performs the cutting operation without constant observation and adjustment of the controls by an operator. The equipment may or may not perform loading and unloading of the work. See Machine Oxygen Cutting.

Automatic Welding—Welding with equipment which performs the welding operation without constant observation and adjustment of the controls by an operator. The equipment may or may not perform the loading and unloading of the work. See Machine Welding.

Machine Oxygen Cutting—Oxygen cutting with equipment which performs the cutting operation under the constant observation and control of an operator. The equipment may or may not perform the loading and unloading of the work. See Automatic Oxygen Cutting.

Machine Welding—Welding with equipment which performs the welding operation under the constant observation and control of an operator. The equipment may or may not perform the loading and unloading of the work. See Automatic Welding.

Manual Oxygen Cutting—Oxygen cutting wherein the entire cutting operation is performed and controlled by hand. See Automatic Oxygen Cutting and Machine Oxygen Cutting.

Manual Welding—Welding wherein the entire welding operation is performed and controlled by hand. See Automatic Welding and Machine Welding.

The Committee has interpreted the term "Semiautomatic" to mean "operated partly automatically and partly manually" and considers this type of operation as one which is practiced primarily in connection with certain arc-welding processes. Therefore the Committee has not defined a general term "Semiautomatic Welding" but instead has defind the term "Semiautomatic Arc Welding" as follows:

Semiautomatic Arc Welding—Arc welding with equipment which controls only the filler metal feed. The advance of the welding is manually controlled.

Fusion and Penetration

The distinction between "Fusion" and "Penetration" has been a source of considerable confusion and the Committee has made a deliberate effort to clarify these terms and provide proper distinction. The Committee has recognized that the terms "Fusion" and "Penetration" may be applied to welds made by welding processes other than arc or gas welding and therefore the general term "Fusion Welding" has not been defined. Furthermore, the Committee has chosen to restrict the use of "Penetration" to "Groove Welds" only and to designate the term more properly as "Joint Penetration." This was decided because "Penetration" is generally used with the idea of the weld penetrating into the joint. A "Groove Weld" is regarded as being "in the joint" whereas, a "Fillet Weld" is regarded as being "on the joint." Therefore, the term "Joint Penetration" does not apply to "Fillet Welds." This is a new and rather startling concept which must be thoroughly understood and adequately comprehended in order to appreciate the significance of the definitions established by the Committee.

The "Groove Weld," being "in the joint," is regarded as fused with the base metal throughout the extent of base-metal surface exposed in the joint for welding, whereas, the "Fillet Weld," being "on the joint," is fused with the base metal throughout the extent of base-metal surface exposed for welding between both toes of the "Fillet Weld" and the root of the joint. If the weld desired is to penetrate the joint to any prescribed extent, then the joint must be suitably prepared or set up to permit such penetration or else the welding must be performed so as to obtain the minimum penetration desired. In such cases the weld is regarded as a "Groove Weld" to which the term "Joint Penetration" or "Root Penetration" may be applied.

This concept visualizes that "Fusion" is measured as "Depth of Fusion" or the depth to which fusion has progressed into the base metal normal to the original base-metal surface on which welding was performed. This means that a "Depth of Fusion" should exist with respect to each base-metal surface involved by the welding operation. In a "Groove Weld" the "Depth of Fusion" is measured with reference to the "side walls" of the groove whereas penetration is measured with reference to the distance the weld has progressed into the depth of the joint. In a "Fillet Weld" the term "Depth of Fusion" only applies and it applies with reference to the original surfaces of the base metal upon which the weld was deposited.

Accordingly, the Committee has established the following nomenclature with their respective definitions:

Fusion—The melting together of filler metal and base metal, or of base metal only, which results in coalescence. See Depth of Fusion.

Depth of Fusion—The distance that fusion extends into the base metal from the surface melted during welding.

Complete Fusion—Fusion which has occurred over the entire base-metal surfaces exposed for welding.

Incomplete Fusion—Fusion which is less than complete.

Joint Penetration—The minimum depth a groove weld extends from its face into a joint, exclusive of reinforcement.

Root Penetration—The depth a groove weld extends into the root of a joint measured on the center line of the root cross section.

Complete Joint Penetration—Joint penetration which extends completely through the joint. See Joint Penetration.

Partial Joint Penetration—Joint penetration which is less than complete.

Inadequate Joint Penetration—Joint penetration which is less than that specified.

Root of Joint and Root of Weld

The Committee regards these terms as of primary significance in connection with prescribing details of joint geometry, joint design or joint welding procedure, since they involve the element of location by reference to a particular point, line or area in the joint or weld cross section.

The term "Root of Joint" applies to the unwelded joint and is considered to be that region or part of the joint cross section where the members to be joined reach their closest proximity. Therefore, the "Root of Joint" may be a point, a line or an area in the joint cross section but, after the joint has been welded, the "Root of Joint" no longer exists and the term has no significance in the welded joint.

The greatest significance of "Root of Weld" is considered to be that indicated by its use in connection with "back chipping," "gouging" or "grinding" a weld at its back in order to prepare for welding that side of the joint to obtain complete joint penetration. After the joint has been welded, as required by the joint design, the "Root of Weld" assumes a minor significance since in this case the reference to "Root Passes" or "Root Beads" indicates those deposits of weld metal which were laid in and adjacent to the "Root of Joint" shown in the cross section of the unwelded joint.

Accordingly, the Committee has established the following nomenclature with their respective definitions:

Root of Joint—That portion of a joint to be welded where the members approach closest to each other. In cross section the root of the joint may be either a point, a line or an area.

Root of Weld—The points, as shown in cross section, at which the bottom of the weld intersects the base-metal surfaces.

Root Face—That portion of the groove face adjacent to the root of the joint.

Root Edge—A root face of zero width. See Root Face.

Root Gap—See Root Opening.

Root Opening—The separation between the members to be joined, at the root of the joint.

Root Radius—See Groove Radius.

Joint Geometry and Joint Design

The Committee considers that the term "Joint Geometry" is intended to refer to the unwelded-joint contour in cross section as the joint is set up for welding. The term "Joint Design" is considered to include "Joint Geometry" plus the outline of the completed weld together with the build-up sequence used in depositing the weld metal. Joint properties are not considered to be included by either term since these properties depend upon Joint-Welding Procedure which cannot be prescribed by Joint Design alone.

Accordingly, the Committee has established the following nomenclature with their respective definitions:

Joint Geometry—The shape and dimensions of a joint in cross section prior to welding.

Joint Design—The joint geometry together with the required dimensions of the welded joint.

Joint (Unwelded)—The location where two or more members are to be joined by welding.

Joint (Welded)—See Welded Joint.

Welded Joint—A union of two or more members produced by the application of a welding process.

Throat of Weld and Size of Weld

The term "Size" is generally used to indicate "extent" or "magnitude" but when used with reference to a weld the Committee considers that it is intended to refer to a specific dimension or a combination of dimensions of the weld. It is considered that the term "Throat" is used with reference to the "net" or "minimum" dimension of the weld in cross section.

With reference to a "Groove Weld" the Committee considers the two terms "Size" and "Throat" to be synonymous but with reference to a "Fillet Weld" they are not. In the "Groove Weld" the "Size of Weld" means the net effective cross-sectional dimension of the weld, which is the "Throat." This dimension is determined by the depth of the "Groove" plus the "Root Penetration." Therefore, it is necessary to define only one of these two terms for "Groove Welds." The Committee has chosen to define "Size of Weld" for "Groove Welds."

In a "Fillet Weld" the "Size of Weld" is considered to refer to the lengths of the legs of the fillet. For "equal-leg" fillets only one leg length is referred to for "Size," whereas, for "unequal-leg" fillets both leg lengths are included. In both cases the leg lengths refer to the lengths of the legs of the largest right triangle, a theoretical figure, which can be inscribed within the weld-metal cross section of the fillet weld. The "Throat" of a "Fillet

Weld," being a minimum dimension of the cross section, is the minimum distance from the root of the fillet weld to its face. For design purposes a "Theoretical Throat" is considered to indicate the minimum distance from the root of the joint to the hypotenuse of the theoretical right triangle previously referred to.

Accordingly, the Committee has established the following nomenclature with their respective definitions:

Size of Weld—
- Groove Weld—The depth of chamfering plus the root penetration when specified.
- Fillet Weld—
  - Equal-Leg—The leg length of the largest isosceles right triangle which can be inscribed within the fillet-weld cross section.
  - Unequal-Leg—The leg lengths of the largest right triangle which can be inscribed within the fillet-weld cross section.

Throat of a Fillet Weld—
- Theoretical—The distance from the beginning of the root of the joint perpendicular to the hypotenuse of the largest right triangle that can be inscribed within the fillet-weld cross section.
- Actual—The shortest distance from the root of a fillet weld to its face.

Welding Procedure and Joint Welding Procedure

The term "Procedure" is interpreted to mean "manner of doing" and the term "Welding Procedure" to mean "manner of welding." However, the Committee has chosen to distinguish between the manner of welding a complete weldment and the manner of welding any particular joint in that weldment by defining the terms "Welding Procedure" and "Joint Welding Procedure."

Accordingly, the Committee has established the following nomenclature with their respective definitions:

Welding Procedure—The detailed methods and practices, including joint welding procedures, involved in the production of a weldment.

Welding Sequence—The order of making the welds in a weldment.

Joint Welding Procedure—The materials, detailed methods and practices employed in the welding of a particular joint.

Joint Welding Sequence—See Build-Up Sequence.

Build-Up Sequence—The order in which the weld beads of a multiple-pass weld are deposited with respect to the cross section of the joint. See Block Sequence and Longitudinal Sequence.

Welder, Welding Operator and Welding Machine

The Committee recognizes that the use of the term "Welder" to indicate a machine which performs the welding operation or a machine which supplies power for electric welding or an individual who is capable of performing manual welding operations leads to considerable confusion in interpretation. Also the use of the term "Welding Operator" to indicate both the operator of a welding machine and the individual who is capable of doing manual welding is somewhat ambiguous since these two individuals do not necessary have the same degree of welding skill such as to be always interchangeable.

Furthermore, the Committee considers it to be appropriate that the terms "Welder" and "Welding Operator" be applied to the individual only and that the machine performing the welding operation be referred to as the "Welding Machine." The equipment which supplies current for electric welding should be referred to as either "Welding Generator" or "Welding Transformer." Similar principles apply to the oxygen-cutting processes.

Accordingly, the Committee has established the following nomenclature with their respective definitions:

Welder—One who is capable of performing a manual or semiautomatic welding operation.

Welding Operator—One who operates machine or automatic welding equipment.

Welding Machine—Equipment used to perform the welding operation. For example, spot-welding machine, arc-welding machine, etc.

Welding Generator—A generator used for supplying current for welding.

Welding Transformer—A transformer used for supplying current for welding.

Weldor—See Welder.

Oxygen Cutter—One who is capable of performing a manual oxygen-cutting operation.

Oxygen-Cutting Operator—One who operates machine or automatic oxygen-cutting equipment.

Gas Cutter—See Oxygen Cutter.

Burner—See Oxygen Cutter.

Acknowledgments

It must be recognized that the points which have been discussed here constituted only a part of the material involved in the A.W.S. Nomenclature Revision. The A.W.S Committee on Definitions and Chart is grateful to all those members of the Society and representatives of industry who have contributed time and thought to a careful consideration of the Committee's problems, as well as the results of its activities, and have offered constructive criticisms.

Welding Applications in Automotive Construction

The production of the modern automobile is greatly assisted by the various welding processes. The solution of some of these high-speed production problems is clearly outlined

by John F. Randall

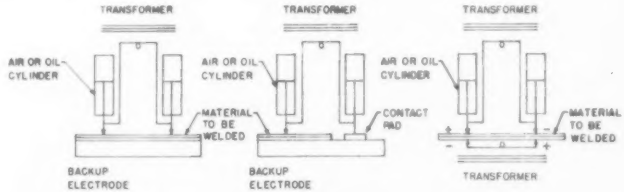
IN THE modern automobile, welding processes are the primary method of fabrication. There are apparently no exact data available on the total number of welds included in a completely assembled modern automobile. However, the magnitude of the welding operations can be illustrated by considering the amount of welding required for the fabrication of two of the major components.

The average automotive body, as presently designed, contains over 8000 spot and projection welds. Accordingly, in order to produce 5000 bodies per day, an automotive body plant must make approximately 40,000,000 resistance welds in a 24-hour period.

In the newer designs of automotive frames, there is a definite trend to replace riveted construction with arc and resistance welding with a consequent increase in frame rigidity and fatigue strength. A typical frame of the newer design has approximately 600 in. of arc welding and about 170 resistance welds. About 450 of the 600 in. arc deposited by automatic arc welding with the remaining 150 applied by the manual metal-arc process. Accordingly, to produce such frames at a rate of 5000 per day, an automotive frame plant must complete approximately 250,000 ft. or 47.5 miles of arc welding and 850,000 resistance welds every 24 hours.

It will be obvious that there are certain special conditions which arise because of the extremely high production rates required for welding operations. For example, a production schedule of 5000 components per day requires over 330 parts per hour if the schedule is to be met with two shifts totaling 15 hours. When a particular component is used in multiple quantities on a single car, production rates pyramid rapidly. For example, 16 valve push rods are required for an 8-cylinder engine. Accordingly, for 5000 engines per day, a total of 80,000 valve push rods must be welded in each 24-hour period. This corresponds to approximately 5500 welded units per hour.

These extremely high hourly requirements result in a different approach to production welding problems. Obviously, in such cases, specialized equipment is both desirable and necessary if the requirements of high production rates and minimum cost per component are to be met. Methods requiring high degrees of manual skill and control of quality and production rate by the operator must be eliminated to the greatest possible extent. In all cases, costs are the determining factor in the selection of a welding method for automotive parts, and the saving of a fraction of a cent per part represents a major sum of money during a year's production.



TYPICAL SECONDARY CIRCUIT ARRANGEMENTS

Fig. 1 Schematic diagram of welding circuits

Fig. 2 Multiple-transformer press-type welding machines for the quarter panel

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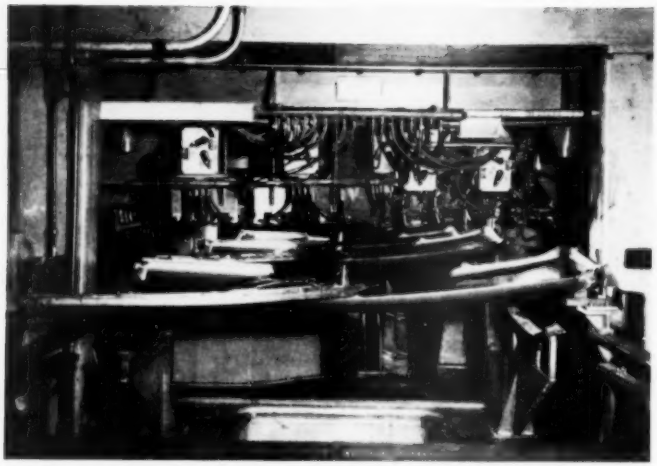

Fig. 3 View of entrance end of quarter-panel welding machines

Among the requirements which must be considered in selecting welding equipment for high production low-cost automotive construction are the following:

1. Ability of the method to meet the required production rates.
2. Reliability and ease of maintenance of the equipment to minimize down time.
3. Minimum dependence on operator skill and working speed.
4. Minimum operating labor and floor space requirements.
5. Adaptability to a straight line flow of work.
6. Ease of modification to meet changed design requirements.

A study of these factors will indicate that resistance welding methods satisfy a greater number of these requirements than does any other welding process. For this reason, there is a preference in the automotive industry for resistance welding whenever such methods are applicable.

Within the last year or eighteen months, the problems of high rate production of welded assemblies at minimum cost have been approached from a radically different angle. This has been made possible by the development of welding equipment capable of producing assemblies as fast as the major components are stamped. With this method, the welding machines are integrated with the stamping press lines for major components. When suitably designed, fast operating welding equipment is placed in series with the stamping presses and a straight line flow of material can be obtained from the original steel blank to the finished major component. The welding machines can then be synchronized with the stamping presses; and the transfer of material through the stamping presses and welding machines and from one to the other can be accomplished by suitable automatic handling equipment which does not require manual effort on the part of the operators.

High-speed welding equipment has been developed which is capable of producing 300 or more assemblies per hour, with each assembly containing from 100 to 300 resistance welds. The basic principles of this type of resistance welding equipment (recently placed in operation in the automotive industry) can best be outlined by describing the separate components used in its assembly. These are as follows:

(*a*) A four-post, mechanically operated, rapid action press on which the bottom platen is movable.

(*b*) Guide rails or a conveyor passing through the press to support or move the work.

(*c*) A suitably contoured fixture which contains copper backup electrodes and is mounted on the lower press platen.

(*d*) A number of small resistance welding transformers which are usually mounted on the stationary upper press platen.

(*e*) A multiplicity of hydraulically operated welding guns which are attached to the transformer secondaries.

(*f*) A suitable hydraulic pressure system.

(*g*) An electronic welding control panel.

Before describing the operation of these special-purpose resistance welders, three different secondary circuit arrangements will be described which can be used for making spot or projection welds in multiple transformer press type welders. Figure 1 is a schematic diagram of three useful circuits.

The diagram to the left illustrates the electrical connections for a series weld. Whenever applicable, this circuit is the most advantageous type for use in high-speed resistance welding machines. An examination of the diagram will indicate that the welding current flows from one of the top electrodes into the upper steel sheet and then divides between three paths. For the purpose of illustration, consider that the current is flowing from the upper right-hand electrode down into the material. A portion of the current will flow across the top sheet and return through the upper left electrode to the transformer. Another portion passes down through the top sheet into the lower steel sheet, across that sheet, up through the top sheet and returns to the transformer through the upper left electrode. However, the major portion of the current will flow from the right-hand electrode directly down through both sheets into the copper backup electrode, along the backup electrode to a point under the upper left electrode, up through both sheets and return to the transformer. The portions of the current following either

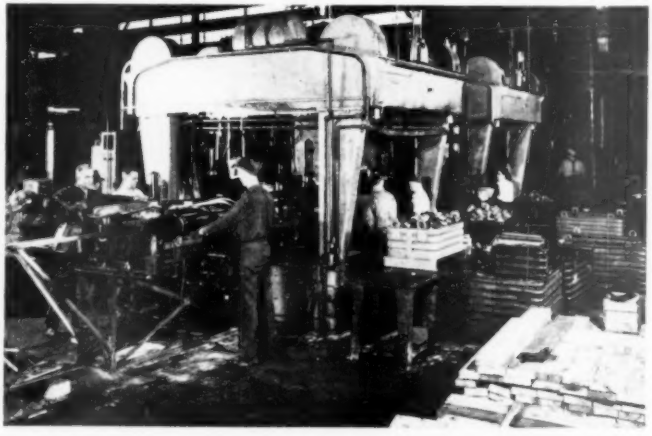

Fig. 4 General view of stamping press—welding machine line for the Ford rear floor pan

of the two latter paths are effective in producing the desired welds. That current which passes through the top sheet performs no useful function.

From an examination of these current conditions, it will be evident that the series welding circuit can best be applied when relatively thin material is being welded and when the separation between the two upper electrodes is greater than some minimum value. Otherwise an abnormally large portion of the current will shunt across the top sheet. The minimum separation of the electrodes is largely determined by the thickness of the material being welded. It should be noted that in the case of the series weld, two spots are produced for each transformer secondary loop. The welding current required is approximately the same as that necessary for one weld with the direct welding circuit.

The center diagram of Fig. 1 shows a special form of a direct weld as it may be used in a large press type welder. An examination of the circuit will show that there are no shunt paths available for the current except those which may exist through previously made welds. A direct weld is usually necessary when three thicknesses of material are being joined or when spots are to be located close together in relatively heavy metal. With this circuit, only one weld is produced for each transformer secondary loop.

The right-hand diagram of Fig. 1 illustrates a specialized circuit using two transformers with the connections so arranged that the polarity of the matching electrodes is always opposite. Although the shunt paths existing with series welds are still present, they become less important with this arrangement. It will be noted that although this circuit produces two welds, it requires two transformer secondary loops and, accordingly, only one weld is made per transformer secondary.

The small transformers are usually mounted on the stationary upper platen of a four-post press. A typical transformer used for this application is rated at 35 kva. and has two individual secondary circuits. Thus, a single transformer can produce four spot welds when used with a series weld circuit. A single welding machine may have from five to thirty such transformers. The use of small transformer units is possible because they can be located very near the point where the welds are to be made. This reduces the size and impedance of the secondary circuit. This reduction in circuit impedance lowers the kva. demand required to produce the welds. All of the transformers in a single welding machine are usually energized simultaneously. However, the controls can be arranged to fire them in groups if power supply is a major problem. Frequently the transformers are grouped and distributed between the three phases of the incoming power supply.

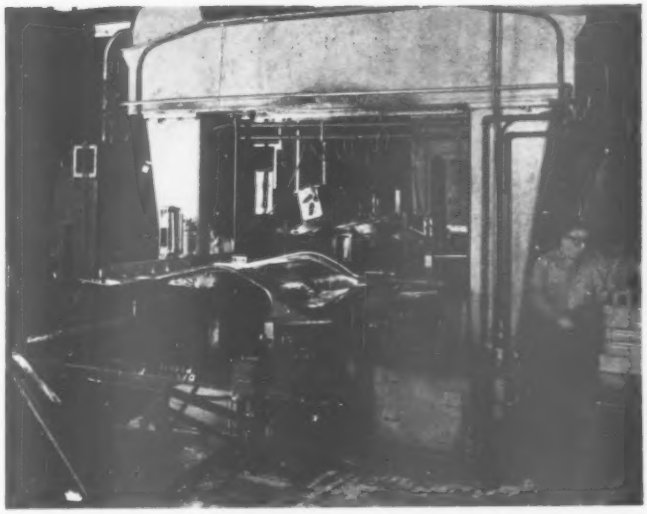

Fig. 5 Close-up of final welding machine on the Ford rear floor pan line

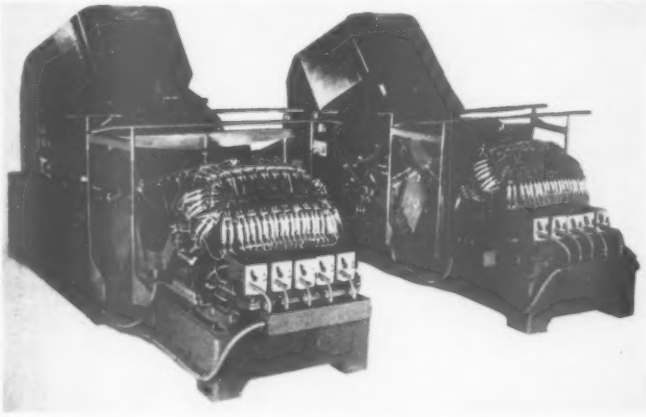

Fig. 6 Two special resistance welding machines used for producing the Ford roof-panel assembly

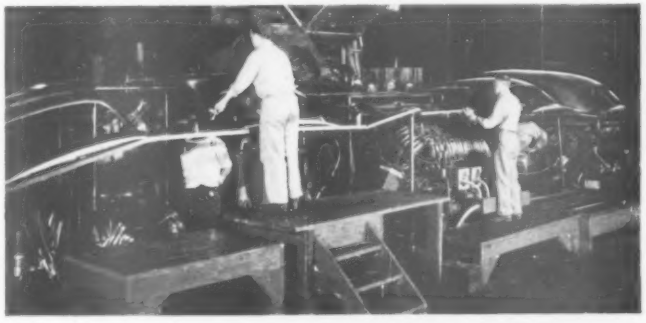

Fig. 7 General view of one of the roof-panel welding lines

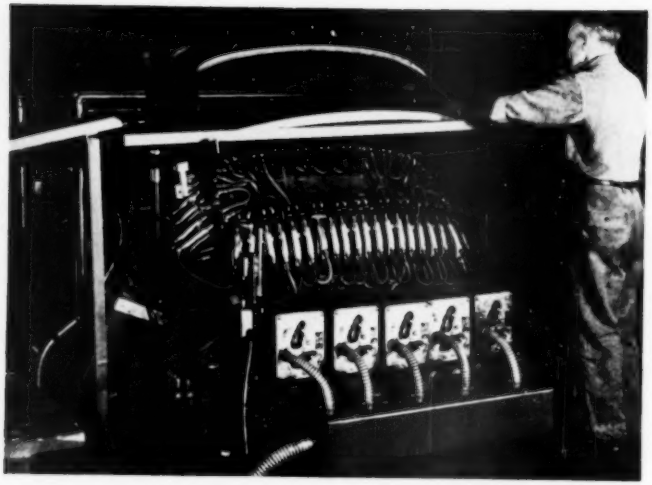

Fig. 8 Close-up of roof-panel welding machine. Panel ready for lowering into welding position

The control panels normally used with multiple transforme machines are of the fully electronic nonsynchronous type employing ignitron tubes and a timer (usually of the N.E.M.A. 3B type).

The normal operation sequence of a multiple transformer type resistance welding machine will next be described.

The part to be welded is moved into proper position in the press on the rails or conveyor. This is usually accomplished mechanically by suitable automation. The bottom platen of the press rises, lifting the part on a properly designed backup electrode, bringing it in contact with the hydraulically loaded guns in which the welding electrodes are mounted. These guns are connected by jumpers to the small transformers described previously. The gun and transformer units are mounted on the stationary upper platen. When the part is in contact with the welding electrodes, the electronic panel energize the transformers and the welds are completed. The press platen then drops returning the material to the rails or conveyor. The next part moves into welding position and, at the same time, the part just welded is moved out of the opposite side of the press.

Figure 2 illustrates the general principles of a machine which operates as described in the preceding paragraph. In this case, there are two four-post presses placed in series. The part being welded is the quarter panel of the 1949 Ford. These two welding machines make 105 welds and have 27 transformers mounted in them. A few of the transformers can be seen in the upper center of the figure where they are attached to the stationary upper platen of the press. In this particular picture, the bottom platen of the press is in the up position and the work is in contact with the hydraulic welding guns. Figure 3 shows another view looking into the entrance end of these same machines. In this view, the press platens are in the down position and although the hydraulic guns are not readily visible, the transformers, water cooling manifolds and hydraulic lines can be clearly seen. This particular operation does not have as high a production requirement as some others, and panels are normally produced at the rate of 150 per hour.

Figure 4 shows a general view of the multiple transformer press welders and stamping presses used for the production of the rear floor pan for the 1949 Ford. In the background, there are three stamping presses (one of which is readily visible) and in series with these presses are two multiple-transformer press-type welding machines. The material is moved from the first stamping press to the end of the line entirely by means of suitable automation. A close examination of the welding presses will reveal some of the hydraulic welding guns and electrodes near the center of the last machine. Figure 5 shows a close-up of the exit end of this floor pan line with a pan elevated into welding position in the last machine. In this view, the hydraulic welding guns can be clearly seen with the electrodes in contact with the floor pan. To the left of the machine is the three-phase elec-

Fig. 9 Additional view of roof-panel welding machine showing transformer connections and hydraulic welding guns

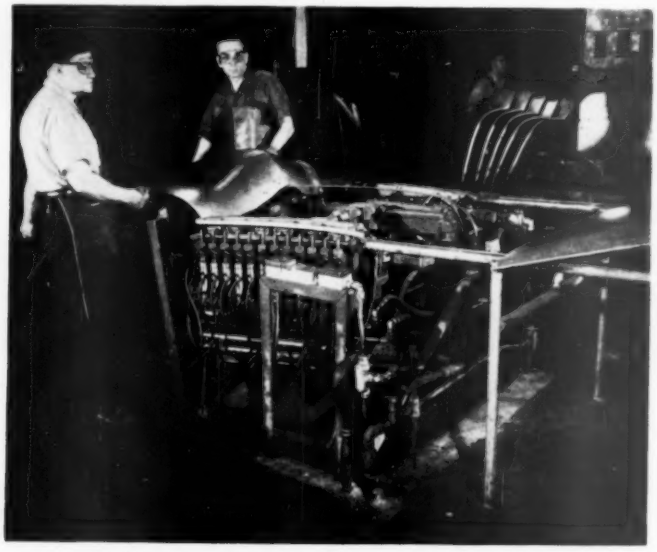

Fig. 10 First machine in hood-panel welding line

tronic panel which controls the welding current.

This floor pan line is an excellent example of the new approach to resistance welding equipment. It is possible for this integrated stamping press and welding machine line to produce over 300 completely assembled floor pans per hour with approximately 100 welds in each pan. This means that the welding machines are making about 30,000 welds per hour or 500 welds per minute.

Figure 6 is a view of two resistance welding machines that are used on different lines for the attachment of the rear window frame, windshield header, etc., to the roof panel. These machines are a departure from the four-post press type previously described, but they still utilize the multiple-transformer principle. Each of these machines has 28 transformers and makes 110 spot welds.

Figure 7 shows a general view of the roof panel welding line with the machine of Fig. 6 located in the right center of the peiture. In this line the roof panels move in over the machine and are lowered into the welding position.

Figure 8 is a close-up of a roof-panel welding machine with a panel in place ready to be lowered into welding position. A number of the transformers and hydraulic welding guns can be clearly seen in this illustration. Particular attention is directed to the backup electrodes for each pair of hydraulic guns. It will be noted that they are arranged to produce series welds.

Figure 9 is another view of this same machine ready for operation. However, in this illustration the rear window frame is shown tacked in place by a few spot welds before the roof panel is lowered into welding position. With present methods, this frame is placed over the electrodes instead of being preassembled. This line is capable of welding 200 roof panels per hour.

An example of still another type of special-purpose multiple-transformer welder which does not involve the use of a large press is shown in the next three figures (Figs. 10, 11 and 12). In this application, the welding operations on a particular part have been divided among three machines placed in series with each other. As a result, no one machine becomes so complicated that maintenance is unduly difficult. These three machines are capable of making approximately 56 welds on the hood panel at a production rate of 360 hoods per hour. There are 16 transformers in the three machines.

Figure 10 illustrates the first machine

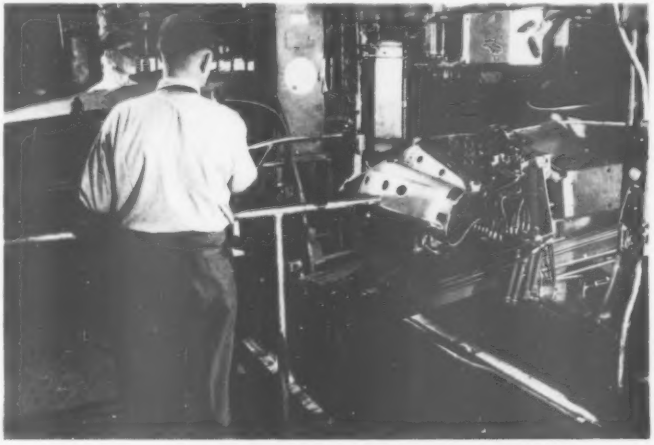

Fig. 11 Second machine in hood-panel welding line

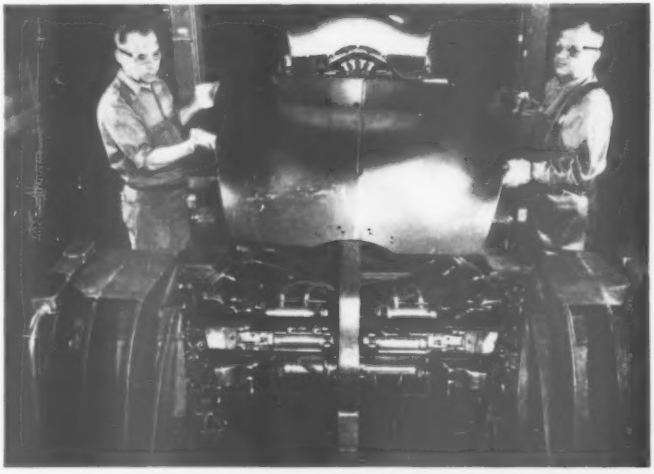

Fig. 12 Third and final machine in hood-panel welding line

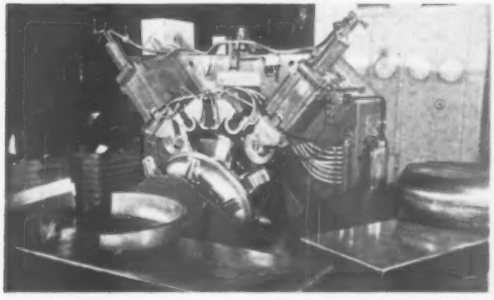

Fig. 14 Wheel housing series seam welder with fixture in loading position

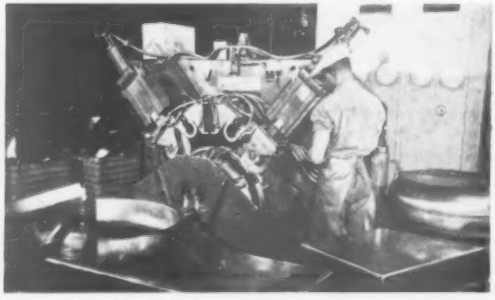

Fig. 15 Wheel housing seam welder in operation

in the series. This machine attaches the side reinforcements to the side flange of the hood panel. The reinforcement is a channel and can be seen in place over the backup electrodes of the machine. This particular machine makes 24 series welds and has six transformers.

The second machine (shown in Fig. 11) attaches the hood inner panel to the front flange and top of the outer panel. The inner panel can be seen in the welding machine before the outer panel has been placed in the proper position for welding. When the machine is operated, the inner panel is moved upward and forward into position and 20 series welds are made. This machine has five transformers. Note particularly the transformer and four welding guns located above the hood inner panel at the upper right.

Figure 12 shows the machine used for the final welding operation on the hood panel. In this machine, the remaining welds are made between the inner and outer panel at the sides and also through the three thicknesses of the outer panel, the inner panel and the side reinforcements. These three-thickness welds are made as direct welds instead of series welds. This machine has five transformers and makes eight series welds and four direct welds.

The equipment described previously is designed for resistance spot and projection welding on body sheet metal. However, a great many other welding processes are used in automotive construction. A particularly interesting application is shown in Figs. 13, 14 and 15.

Figure 13 is a picture of a special double head resistance seam welder which is used for joining two halves of the wheel housing of the 1949 Ford. This part is shown at the lower left of the illustration. This seam welder is equipped with two welding wheels which are both located on the same side of the part being welded. A solid copper backup bar is used on the other side of the joint. One welding wheel is connected to each side of the welding transformer secondary. The current passes from one wheel down through the work into the copper backup and then to the area under the second wheel; up through the work into this wheel and back to the other side of the transformer. This is an example of a series seam weld in which the current flow paths are similar to those described previously for series spot welds. This machine operates at extremely high speeds and is capable of producing 180 parts per hour with a 48-in. long, watertight joint in each part. During welding, the wheels are traveling at a speed of 280 in. per minute; therefore the two wheels produce a weld at the rate of 580 in. per minute. The welding time per part is five seconds. A continuous flow of welding current is used; i.e., there is no "off time."

Figure 14 shows a part loaded in the machine. Note that the loading fixture is swung forward and the clamps are raised to facilitate placing of the pieces in the machine. Figure 15 is an illustration showing the part actually being welded.

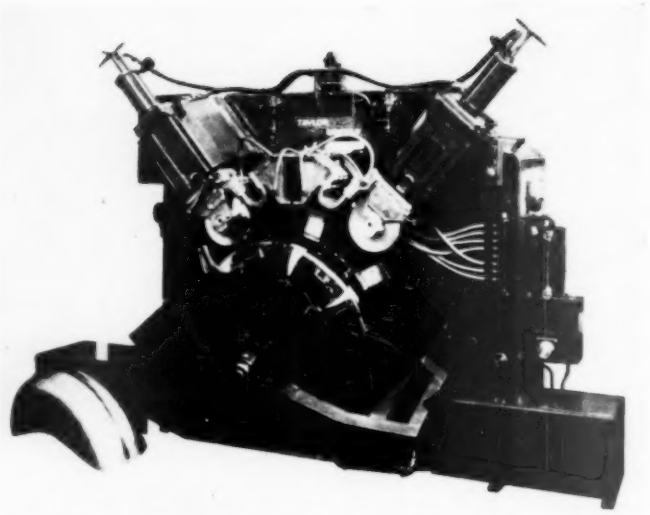

Fig. 13 Special series seam welder for fabricating the 1949 Ford wheel housings

A very interesting new application resulted from the difficulty of obtaining the large sheet sizes required to produce front and rear floor pans. The blank size required for the front floor pan is 60 x 69 in. and that for the rear is 70 x 86 in. Not only are sheets of these sizes difficult to obtain, but they carry a premium price because of width extras. It was therefore proposed that sheets of a narrower width be welded together to form the necessary blanks for the stamping and other subsequent operations on the front and rear

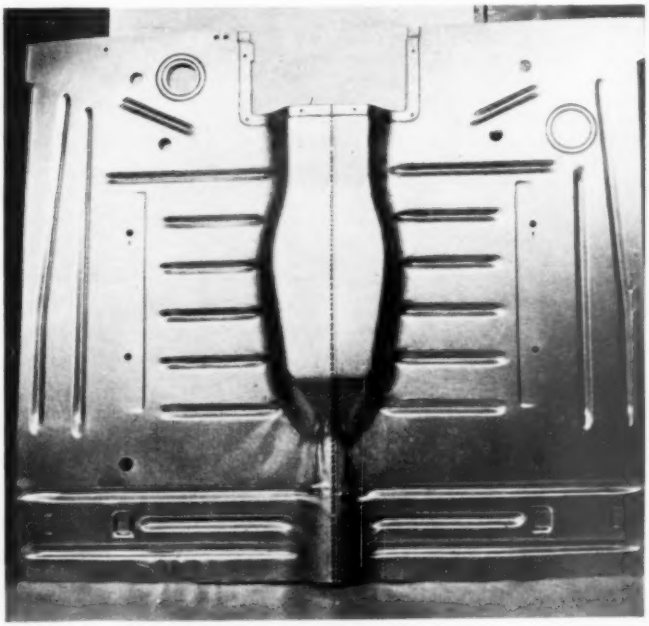

Fig. 16 Front floor pan for the 1949 Ford which has been formed from a welded blank

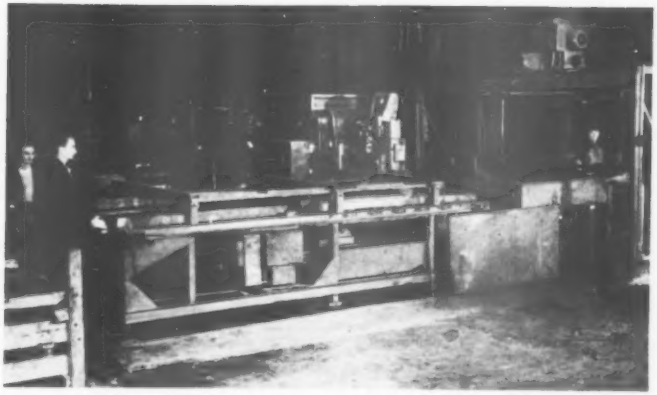

Fig. 17 Special automatic equipment used for seam welding of sheet steel floor pan blanks

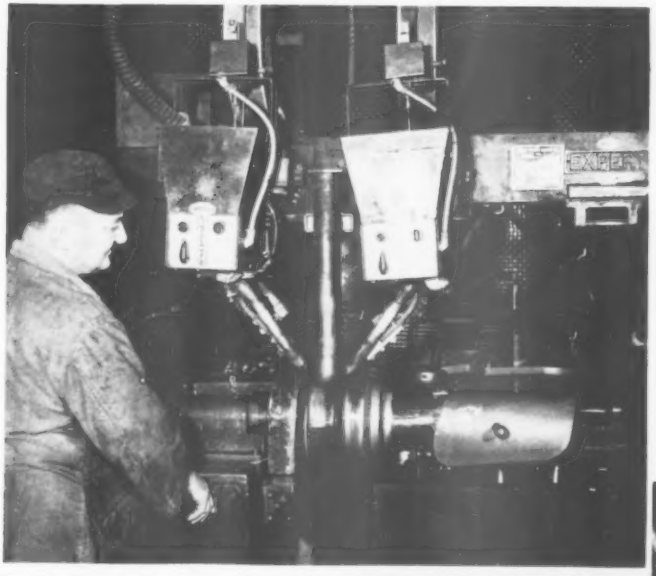

Fig. 18 Automatic submerged arc welding of the reinforcing ring and cover plate to the 1949 Ford rear axle housing

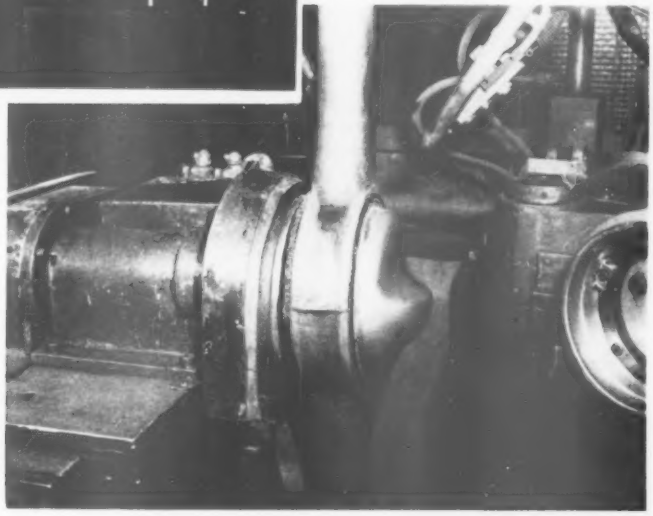

Fig. 19 Close-up of completed welds on the rear axle housing. Clamping device swung back to loading position

floor pans. After some study, it was decided that a seam weld would be the most satisfactory joint since it could readily be made both watertight and strong enough to stand the severe forming operations. The schedule for the two floor pan lines required the welding of 250 to 300 blanks of each size every hour.

Figure 16 is a photograph of a completed front floor pan made from a welded blank. It will be noted that the weld is so located that it is subjected to extremely severe forming stresses.

Figure 17 is an excellent example of a high-speed welding operation requiring a minimum of manpower. The machine in the foreground is used for joining the two sheets that form the front floor pan blank. In the background, there is a similar machine that is used for the rear floor pan blank. The machine in the foreground has been averaging a production of over 300 blanks per hour. The actual seam-welding speed is approximately 460 in. or 38 ft. per minute. As shown in the illustration, only three men are required for the operation of this equipment. The two men at the left load the individual sheets onto a conveyor. These sheets are picked up by the conveyor and, at the proper time, moved forward into the welding wheels. The top of the upper welding wheel can just be seen at the right center of the photograph. Immediately following the welding wheels, the area affected by heat and water is automatically recoiled and the sheet is then carried to the location shown in the extreme right of the photograph and automatically stacked. The man at the right observes the operation of the stacker and visually checks the welding.

A $\frac{1}{2}$-in. lap is used for the seam weld. This lap is obtained by the use of a Z bar without pretacking or any preassembly

Fig. 20 Close-up of the weld joining the medium-carbon, high-sulphur universal joint yoke to the propellor shaft tube

of the sheets prior to welding. The separate sheets are automatically forced into the Z bar by spring loaded rollers in such a way that exactly the proper overlap is obtained for the seam-welding operation. An unusually high weld quality can be maintained with this equipment so that the scrap from weld failures in subsequent forming operations is held to a fraction of 1%.

The various operations described previously all utilize resistance welding processes. However, it should not be concluded that only resistance welding is used in automotive construction. As mentioned earlier, arc welding is extensively used in the fabrication of automotive frames. This process is also utilized in the manufacture of rear axle housings, propeller shafts, etc. The fabrication of one modern rear axle housing involves flash welding, projection welding, approximately 56 in. of automatic submerged arc welding and 12 in. of automatic bare wire welding.

Figure 18 is a photograph of the automatic submerged arc-welding operation which joins the reinforcing ring and cover plate to the rear axle housing. Approximately 56 in. of submerged arc weld is made in this machine. The welding time is 28 seconds and an average of 60 housings per hour can be obtained from this equipment.

Figure 19 is a close-up of a rear axle housing after welding with the clamping plate swung back to the loading position. These welds are required to be absolutely free of leaks and are given a 100% pressure test.

Another operation of considerable interest is the weld between the end of the $2^3/_4$-in. diameter, $^1/_{16}$-in. wall, propeller shaft tube and the medium-carbon, high-sulphur forging that forms one yoke of the universal joint. A weld of this type is made at each end of the propeller shaft tube.

Figure 20 shows a close-up of the submerged arc weld between a yoke and one end of the tube. Before the weld is made, the yoke is pressed approximately $^1/_{\text{?}}$-in. into the tube. Figure 21 is a photograph of the production machine used to weld the yokes to the drive shaft tube. After the yokes have been pressed into the end of the tube (this can be accomplished on the fixture shown at the front of the machine), the shaft is permitted to roll down inclined ways into a position under the welding heads. On reaching this position, the shaft is lifted vertically until it comes in contact with the rotating drive roll shown in the center of the illustration. The wire feeds down, the flux is automatically released, the arc starts and the tube rotates through the proper number of degrees to complete the weld. The tube is then lowered onto the ways and rolls out the back of the machine. The actual welding time is $7^1/_2$ seconds, and the machine is capable of producing 250 welded shafts per hour.

To summarize the information on welding in automotive construction, three principal highlights should be mentioned:

(*a*) Welding has become the primary method of fabrication in automotive construction and practically every known welding process is employed.

(*b*) Because of the lesser dependence on operator skill and its adaptability to high production, resistance welding methods are preferred whenever applicable.

(*c*) The recent development of high-speed multiple transformer resistance welders has greatly facilitated high rate production of welded assemblies at minimum cost. These machines are capable of producing welded assemblies as fast as the stamping presses operate and permit a straight line flow of material from the initial blank to the finished major component. This facilitates the use of automatic material handling equipment.

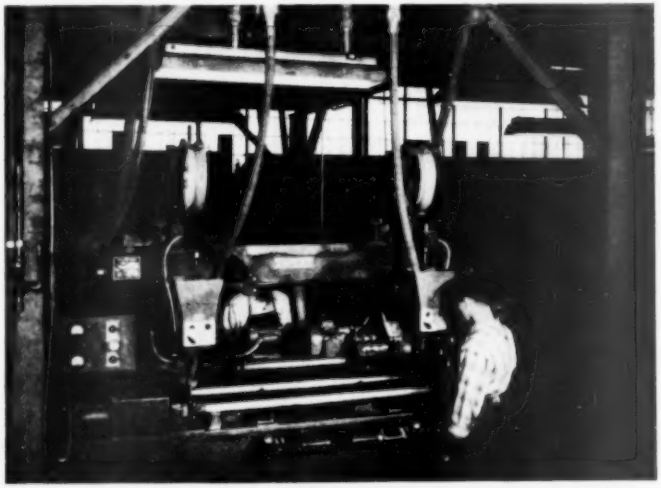

Fig. 21 Production machine for welding universal joint yokes to the propeller shaft tube

Control and Inspection for Quality Welds

The proved inspection methods and ideas surrounding their application in shipbuilding, pressure vessels and piping are thoroughly covered

by J. Lyell Wilson

GENERAL

WHILE there is fairly general agreement that some inspection is necessary or desirable in most construction work, not too much has been said or published regarding the guiding philosophy for good inspection in general nor with respect to the differentiation between self inspection and independent inspection. Typical of such a condition is the generality, "As in the case of much fabricated work, that which is done by a welding process is often required to be inspected during the course of construction, either by the purchaser, by the manufacturer or by reason of some legal code requirements." (*A.W.S. Recommended Practices for Inspection of Fusion Welding*, 1942.)

However, no reputable manufacturer wants his products or parts of products rejected by an independent inspection and therefore such a manufacturer has for years included within his organization what is referred to as self inspection. This has been true not only for welding but also in diversified engineering works. Such methods are implied by the statement, "In any kind of fabrication or construction work, inspection is made easy or more difficult (more or less effective) as a result of the amount and adequacy of the direct supervision and control exercised over the production forces. One of the principal duties of an engineering (independent) inspector is to make sure that competent and sufficient supervision and an adequate system of control are provided; although he should not attempt to dictate the details of the system of control that lie outside the province of engineering (independent) inspection." (Grover, *Manual of Design for Arc Welded Structures*, 1946.)

However, of all that has been written, said or published on the subject, the best, most practical and useful data will be found in *Inspection Handbook for Manual Metal-Arc Welding*, by the AMERICAN WELDING SOCIETY, 1945.

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This paper was first presented before the New York Section, A.W.S. on January 14, 1948. In November 1948, it was presented to the Section at Pascagoula (jointly Mobile-New Orleans), Birmingham Section, Chattanooga Section and the Nashville Section, all AWS.

With regard to fundamental considerations there should be no differences as between self inspection or independent inspection. However, there is a practical difference between them with respect to time, self inspection being continuous while independent inspection is, at best, intermittent. While this is important in welding and forms a specific part of the following discussion subsequent reference to the inspector implies independent inspector.

Inspect: To view or examine for the purpose of ascertaining the quality or condition, discovering errors or to oversee.

Survey: To view with a scrutinizing eye; to inspect for a purpose; to examine with reference to condition, situation or value.

In a broad sense by representing the buyer or user an inspector is actually an adviser whose main function is to interpret specifications for the producer and insure a product suitable for the purpose intended by the buyer. Codes of acceptability standards, of testing procedures and techniques, and of recommended practices are merely the tools intended to facilitate the use of inspectional methods and to provide criteria for acceptability. As such, the availability of some code specifically covering a certain product will no more insure good inspection of that product than will a fine micrometer insure accurate machining of some part of that product. However, in the hands of an experienced and skillful mechanic an accurate measuring device is of considerable advantage in producing good quality workmanship. But what is more important is that, even in cases where no means are readily available for gaging workmanship, an expert mechanic will devise something for the purpose and thereby become what is called a toolmaker.

So, too, should a good inspector with the requisite experience be able to meet any situation by first of all applying existing regulations with intelligence and understanding and if none exist that are directly applicable or if those that do exist are vague he should be equally able to establish reasonable methods to fit the case involved.

Along the same lines of thought it seems appropriate to draw a corollary conclusion, viz., since codes are made to facilitate inspection for acceptance they might

be more useful and perhaps more adaptable if more good inspectors were engaged in their formulation.

The present discussion, however, concerns only the inspectional methods and ideas surrounding their application in the production of quality welding. It is not the intention merely to discuss the tools of inspection, i.e., the various material specifications for base materials, the qualification requirements for electrodes, the qualification requirements for welders, the workmanship code requirements for various products such as boilers and other pressure containers and piping, etc. All of these are readily available and may be studied more leisurely like any manual on the use of the micrometer, slide rule or other useful tool. It is also the intention to explore, in this discussion, experience in the application of such codes or tools in the field of welding.

The field chosen is that of metal arc welding in shipbuilding, pressure vessels and piping but the philosophy developed by the discussion is general enough for other fields of application. The views expressed are not individual but are the studied interpretations of a composite group of those experienced in the application of the principal welding codes.

In accordance with the almost universal plea let it be clear at the outset that few if any inspectors like the term, "production welding," because it implies quantity or rapid production. The expression is therefore used only to describe on-the-job finish welding—but good.

ORGANIZATION

Since the character of any organization reflects that of its Chief Executive, it seems obvious that no producer can be expected to turn out quality welding unless that company's top management really is welding minded and includes those who have sympathetic understanding of certain fundamentals necessary for the production of good welding practices. With management of such a character there will be teamwork, not only between designers and production personnel, but also between management and company inspection which will be unhampered by conflict between different crafts and unusual personalities. And the inspection department will be effective in such an organization so that no outside inspector will ever feel the all too common challenge: "We'll lay you ten to one you can't find where we loused up the job."

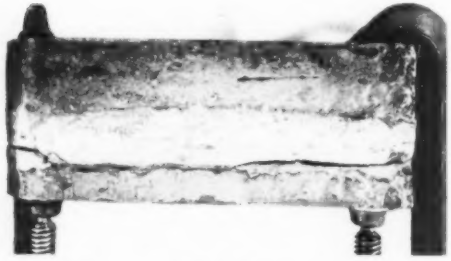


Fig. 1 Top (exposed) view of butt weld in bulwark rail bulb angle

Fig. 2 Underside view of weld in Fig. 1

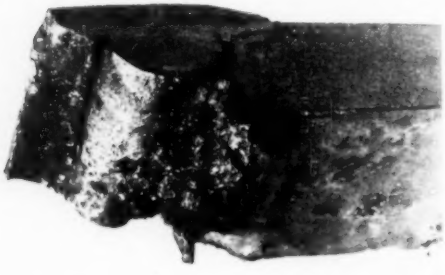


Fig. 3 View of broken joint showing short heavy slug

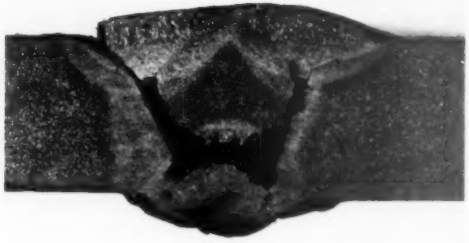


Fig. 4 Etched section view of Fig. 3

Figs. 1–4 Welded butt joint in bulwark rail bulb angle

The failure of this joint, which had been "slugged," resulted in a major and almost complete casualty.

Figure 1 shows the upper (exposed) surface of cracked joint as it appeared when the two parts of the specimen were clamped together. The final welding passes give no clue to the poor condition on the underside nor the potential danger of the internal condition.

Figure 2, the underside view, shows complete lack of proper cleaning and absence of root pass. The probabilities are that this bulb angle molding was considered relatively unimportant. Nothing is considered insignificant now in welded construction, especially on members of any kind located on the outer boundaries of the hull girder—even attachments.

Figure 3, the diagonal view of the underside of one part of the specimen including the "slug," together with Fig. 4, the macrograph of the full section, etched to show the voids in the welding of this joint, illustrate one of the worst examples of careless work with almost complete absence of fusion and penetration.

Even before the general adoption of welding as a means for joining parts of structures, it was the fixed policy of the more reputable companies to so organize their own inspection departments that an outside inspector would never find the same fault twice. As a matter of fact so well were these activities organized that inspectors from agencies outside the company had little to worry about beyond their own reports and acted mainly in a consulting or advisory capacity.

That type of organizing means good welding because welding more than any other process requires the utmost in control. For example, it has been found by experience that, even when welders and foremen are convinced (after many mysterious difficulties or failures) that it is absolutely necessary to follow a specified procedure in welding, there is still a decided tendency for many, who consider themselves good welders and would not stoop to outright cheating as by slugging, etc., to show little or no hesitancy in following some short-cut methods of their own conception. They probably think either that their own method is better or that any resultant minor defects would never be known. This is not good welding.

To summarize, therefore, the production of good quality welding requires proper and continuous control of design, materials, procedure and technique applied to every step required in the production of any given product. Such control requires careful planning and the complete cooperation of a well-organized personnel. It also requires continuous supervision and shop inspection so set up as to be really effective. Finally the entire organization should be motivated by a definite policy that everyone on the team shall function for the primary purpose of producing good quality welding.

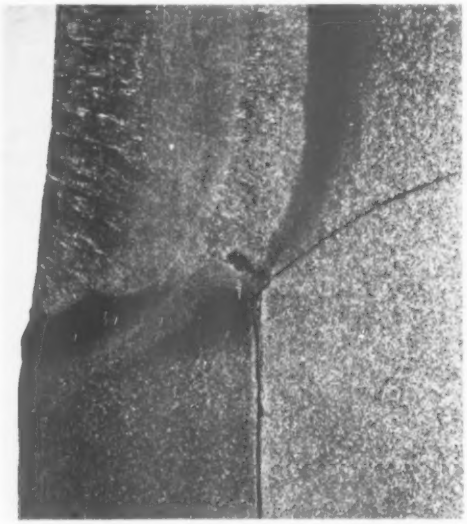


Fig. 5 Macrograph of crack at corner of plug weld

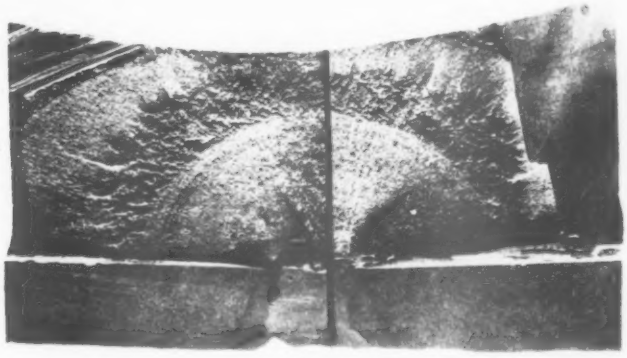


Fig. 6 Macrograph of section at crack in Fig. 5

Fig. 7 Macrograph at crack in opposite end

These macrographs illustrate the manner in which the microcrack which always forms at the bottom of plug-weld sockets progressively results in total failure.

Figure 5, longitudinal (tube axis) section at focal point of failure.

Figure 6, transverse (circumferential) section at same focal point as in Fig. 5.

Figure 7, comparable transverse section at opposite end of plug.

Both Figs. 6 and 7 show typical "oyster shell" fatigue failure characteristics emphasizing the notch-like formation at the bottom of the plug. These are especially pronounced because of such heavy weldments.

Figs. 5–7 Sectionalized part of plug weld formerly used on heavy tube stock and plate attachment of rudders

Of course such an organization will employ only qualified personnel and train its own supervisors and inspectors besides the welding operators whether previously qualified or not. It should be emphasized that one important unwritten operator qualification requirement is the necessity to fit into an organization such as that described.

DESIGN

Whatever the structure or product may be, if it is to be fabricated by welding, its production by good welding begins on the drawing board. Proper design surely helps the welder but to a much greater degree it facilitates the work of inspection. For example, on the point of accessibility alone, if it is difficult to weld a joint because a welder cannot reach it and see it and relax at the same time, it is equally difficult to inspect it and what is worse it is impossible to expect and get good workmanship as a result. In other words and again quoting Grover, "It must be borne in mind that the operator will be wearing a helmet: also that electrodes for vertical and overhead welding are 14 in. in length and those for downhand welding are 18 in. in length." Gouging and re-welding in confined spaces frequently makes the result progressively worse rather than better so that in the final analysis in such cases the inspector is forced to compromise with acceptance of relatively poor workmanship.

Similarly if designers cannot overcome the urge to develop new and unorthodox types of joint details as compared with those of the simplified and recognized standards let them concentrate on improving some of the annoyingly difficult details such as the permissible expediency of using chill rings in pipe joints without definite specifications for absolute control. In any case it should be mandatory that designers, who insist upon toying with the ordinary standard joint details, should themselves be required to demonstrate that any such new joint can be welded satisfactorily before it is permitted but with the added proviso that such a designer shall do all the welding while curled up in a small packing case or otherwise demonstrate ease of execution.

Design should develop along lines of simplification even if it be necessary to change the general form or appearance of a product. In order to minimize the number of welded joints necessary to finish a product every effort should be made to use the minimum number of parts by making the fullest use of machining and forming methods such as flanging; avoid the use of plug welds and always provide for accessibility so that all welding can be done from both sides as it should be done; avoid the use of any welded joints at a point of abrupt discontinuity of section; consider the use of prefabricated subassemblies at complex structural intersections; and above all treat with serious concern any lightest attachment of insignificant fittings because by careless treatment total failure sometimes results. Whatever welding is to be done call for it to be good standard quality welding, thoughtfully planned with knowledge that it can be done well, and thereby learn that good welding depends first on good design.

Learn to design structures without the use of doublings for reinforcement; these were developed only for use in riveting. If reinforcement is necessary, avoid inserts and insist on the proper tapering of the thicker to the thinner member without skimping to provide for a proper joint at the thinner material section. This is good design and it makes for good welding.

Specify in detail all welding data wherever welding is called for and do this by using standard symbols. This is good design and it makes for good welding.

Design should not be considered as final until it has been reviewed critically by both the General Superintendent and Welding Engineer or their equivalents. In other words good welding depends on teamwork as much as, if not more than, anything else. Obviously if design calls for something contrary to the ideas of those who supervise the work or beyond the capabilities of those who perform the work the inspectional problems will be almost insurmountable.

In other words, while good design is a first necessity for the production of good welding, the execution of that good design requires teamwork, fundamentally, continually and literally. If the entire organization from the student welder, helper or tack welder up through the General Superintendent, General Manager and including the President and the Board of Directors is "welding minded," this means good welding. Without some such teamwork no inspector can hope for good welding but every inspector can help create such teamwork.

An old but good philosophy to follow is: "Plan your work, work your plan."

MATERIALS

The base materials used in the construction of most structures are purchased from the steel mills under a recognized standard specification designated by the purchaser or his designer or consulting engineer. In many cases such as for ships' hulls and their boilers the choice of such specification requirements is limited to those approved by some regulatory bodies. The requirements of such regulatory bodies are also sometimes referred to as codes but it is more desirable that they be designated as Rules or Regulations and that the designation Code be reserved for that which is promulgated by an organization having no part in the administration of such standards. Accordingly, Codes may be administered by independent agencies while Rules or Regulations are enforced or administered only by representatives of the regulatory body by which the Rules were promulgated. All standards and recommended practices published by the AMERICAN WELDING SOCIETY are Codes in the sense understood in this discussion.

Such Codes are frequently adopted by regulatory bodies as part of their Rules or Regulations and this procedure is particularly true as applied to materials, electrodes, procedures, etc., for the building of ships, boilers and marine equipment.

In the cases of such structures the material specifications generally follow those of the American Society for Testing Materials or simulate them to a considerable degree. While most of this material is tested at the mills by representatives of the regulatory body none

or very little of it is seen by independent inspectors, except for boiler steel plates, until it arrives at the shipyard. It is of the utmost importance therefore in such cases to understand clearly that any steel in this category is subject to rejection if found defective or otherwise unsuitable in spite of any prior acceptance on physical testing.

Generally speaking there are relatively few occasions when such action becomes necessary, the most common causes being laminations and sulphur segregations dis-

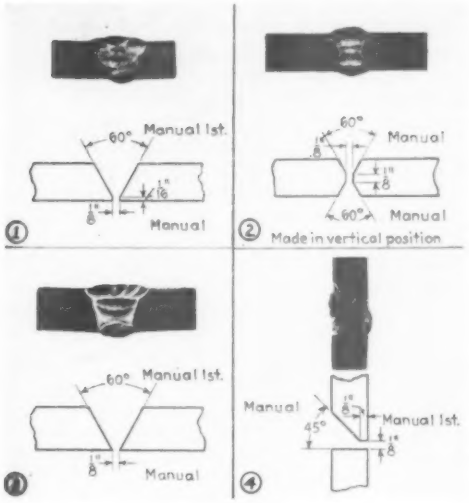


Figure 8

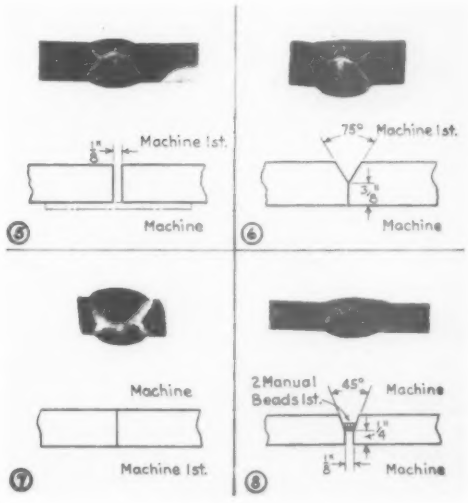


Figure 9

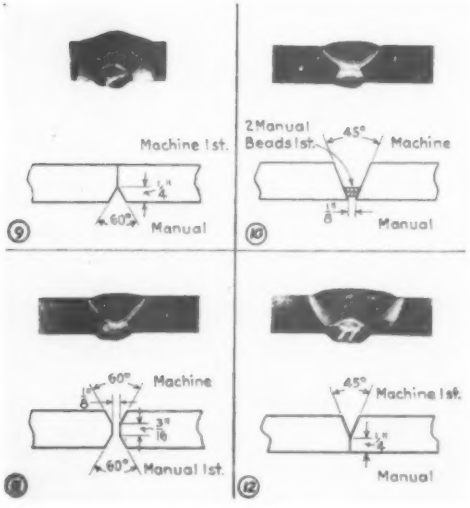


Figure 10

These are illustrative of some of the most commonly used edge preparations as shown on detail drawings and as sectionalized after welding in the average routine procedures. These are not intended to be indicative of ideal welds but rather to convey in some measure the idea that even some of the recognized standards are difficult to produce well in production (see (4) of Fig. 8) and to discourage the uncontrolled invention of more complex designs of edge preparation.

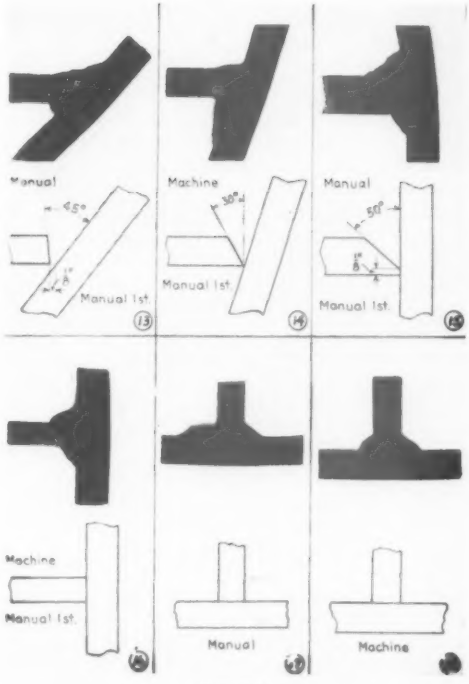


Figure 11

Figs. 8–11

closed during cutting or welding. Since by far the major portion of material used in this industry is ordinary mild steel the problem of weldability and standard qualification procedure has not been too acute except as it is developing in the greater use of low alloys in engineering materials particularly for use at elevated temperatures.

Singularly enough the characteristics in the performance of mild carbon steel have recieved tremendous attention for the past five years. This scrutiny has been directed not so much toward the effects from welding as to the phenomenon of crack propagation in monolithic structures. The scope of these investigations includes fundamental research applicable as well to all types of structures and especially to those subjected to low temperatures in service.

From the point of view of inspection at the place of fabrication, materials should present few problems as regards the choice of type to be used because such things should be completely covered by the design specifications. Nor should they be particularly difficult with respect to Standard Procedures since these details together with electrode designations and joint details should always be clearly given on the design. But what is of paramount importance to material inspection is that welding should not be performed on anything having indefinite identification. This can be assured only by a proper method of classification and identification of all materials received and stored together with complete records of tests carried out at the mills to show compliance with designated specifications.

ELECTRODES

Since it is the practice of regulatory bodies to issue lists of electrodes approved by them for specific purposes this phase of the problem need be of no special concern as such to inspection personnel. It should be emphasized, however, that all inspectors on welded construction should not only be familiar with standard specifications for iron and steel are welding electrodes, but also that they should have some experience in the application of these standards by way of the testing of such electrodes for appropriate qualification. Obviously through such experience inspectors will become better acquainted with the details regarding type designations and specific applications of a given electrode and be thereby better enabled to understand the purpose for which each is intended to be used or the proper conditions surrounding its use.

Apart therefore from the routine necessity of checking the types of electrodes being used against those specified in the design and procedure specifications the greatest concern on the part of inspection with regard to electrodes has to do with two major factors—first, the conditions under which electrodes are stored and second, the verification of the conditions under which each electrode is being used on the job.

With regard to the storage of electrodes, it should be said that on numerous occasions improper storage has been found to be the primary cause for complaints regarding the suitability of a given electrode in its performance on the job. Accordingly it can not be overemphasized that the storage of electrodes should receive the careful attention of all inspection personnel in order to insure that electrodes will not become substandard in quality before they are used.

In connection with the conditions under which a given electrode is being used, inspectors not only have available the characteristics of each electrode but they also should see that a definite procedure is specified on the design and has received the approval of the appropriate regulatory body and then they should make sure that such a procedure is carried out in every respect. Familiarity with standard qualification procedures on the part of the inspectors is not only desirable but of the utmost importance in cases where it may be found that approval has been given to a procedure which departs in some respects from the standards.

In the event that recognized standard qualification procedures are not to be adhered to because of alternatives in connection with the design, it seems obvious that inspection personnel should be concerned with determining whether or not such alternative procedures have also been tested and found satisfactory. In other words, it may be seen that quality control involves an over-all procedure which may be compared to a chain and unless each link is carefully scrutinized in such a chain there is no assurance that a discernible defect does not exist. This will probably result in the weak link causing failure.

WELDERS

The qualification of welding operators has been from time to time one of the most troublesome factors in the application of welding. The importance of the welders' status in the problem of control was at first considered paramount, but has decreased to the extent of being replaced by considerations of qualification procedure which are becoming more standardized and which are more or less coupled with the qualification of operators. The technical aspects of these two problems are sufficiently well presented in Code form by the AMERICAN WELDING SOCIETY as to need no further elaboration. It seems much more important, however, to deal with some of the annoying problems associated with this necessary inspectional activity.

For example, while it may be a simple matter to handle the qualification of operators through such agencies as referred to as regulatory bodies there are at times many difficulties in the independent fields and even in municipal activities through what appears to be complete misunderstanding as to what operator qualification means.

In the first place too much emphasis cannot be placed upon the consideration which has been reiterated on numerous occasions that the qualification of an operator at one place does not necessarily qualify him for another place. Substitute in the foregoing sentence

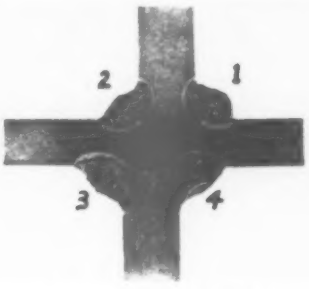
another word such as "job," "plant," "industry," etc., and the answer is still the same, namely, that an operator should demonstrate his ability to perform the particular work on which he is to be employed and unless he has recently qualified or has been continuously engaged on that specific type of work in that particular plant or place or industry, he should submit to retest for requalification.

Some plant managements seem to think that it is necessary only to screen new applicants for jobs by way of accepting only those who have evidence of previous qualification whereas every effort has been made among the regulatory bodies to avoid giving welding operators any certificate or other means of claiming qualification in the event that they leave one job for another. Most requirements insist, as previously stated, that qualification is intended to be strictly a local matter between the management and the regulatory bodies.

Actually the principle underlining considerations of this kind is perfectly simple and should be clearly understood. It involves the fact that such agencies regard it as important that the work of each welding operator be definitely established as in compliance with a given standard and that a welding minded management would no more be content to accept indirect knowledge of such a factor than they seem inclined to be with regard to accepting materials of unknown origin or characteristics. In other words, a welding-minded management should be sufficiently interested in the production of quality welding that they would diligently

Electrode, 1/4 In. Ordinary
Current constant, 210 amp.
Burn off constant, 7 in. per minute
Travel speed variable

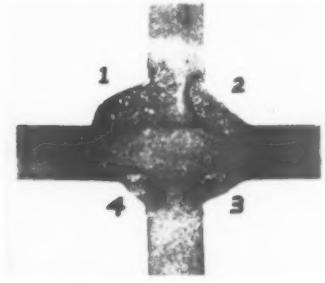
Weld	Travel, In./Min.
1	2.0
2	4.7
3	7.3
4	12.0



Electrode, 1/4 In. Ordinary
Travel speed constant, 6 in. per minute
Current variable
Burn off variable

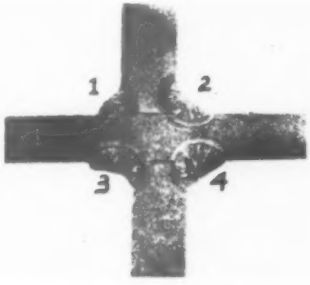
Weld	Current, Amp.	Burn off, In./Min.
1	210	6.8
2	255	8.6
3	340	11.2
4	375	12.2

Electrode, 1/4 In. Ordinary
All 4 welds made with current constant, 290 amp.
Burn off constant, 9.7 in. per minute
Travel speed constant, 4.3 in. per minute



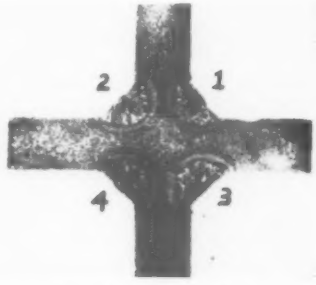
Electrode, 1/4 In. Hot Type
Current constant, 270 amp.
Burn off constant, 9.6 in. per minute
Travel speed variable

Weld	Travel, In./Min.
1	3.1
2	6.5
3	8.3
4	12.5



Electrode, 1/4 In. Hot Type
Travel speed constant, 12 in. per minute
Current variable
Burn off variable

Weld	Current, Amp.	Burn off, In./Min.
1	210	7.1
2	275	9.8
3	320	11.0
4	370	13.0



Electrode, 1/4 In. Hot Type
All 4 welds made with current constant, 340 amp.
Burn off constant, 12 in. per minute
Travel speed constant, 11.6 in. per minute

Figure 12

This series of macrographs with related data is an actual record of progressive stages of improper electrode applications in fillet welding to more suitable electrodes and especially with proper characteristics. The final illustration (24) shows the ideal of the series with the proper characteristics for the particular electrode used.

pursue a policy of examining all new applicants as welding operators and even if they are found in conformity with standard qualification tests they would train them to fit their particular procedures and methods before placing them on production work.

By the general adoption of such policies a considerable benefit would accrue to the welding industry if for no other reason than that it would have a very strong tendency to obviate the necessity for setting up independent laboratories, even in municipalities, for the purpose of checking welder qualification in order that such men can apply for a job. Even if such activities are a necessary part of Building Code specifications, it should be emphasized that the procedure is wrong in principle and all reputable manufacturers or contractors should realize the importance of controlling operators within their own organization.

INSPECTION

The practice of inspection is not peculiar to the welding industry as such but has become more or less routine with practically all important structural work by way of independent inspection and has for years been the routine practice of most well-regulated industry by way of self inspection. In its application to the welding industry, inspection has perhaps become somewhat overemphasized. Perhaps this is because of some of the facts already enumerated whose exposition was intended to show that the control of the welding processes for the purpose of production of quality welding is so dependent upon continuity of effort along inspectional lines. Such considerations might lead the thoughtless to conclude erroneously that welding cannot be as reliable a means of joining structural materials as other processes.

On the contrary it seems reasonable to conclude that a careful consideration of the advantages to be gained by the use of welding processes would be more than enough to warrrant a change from the attitude of smug complacency to that of an earnest desire to become welding minded and care sufficiently for the details as to insure quality commensurate with the importance of a particular product. After considerable experience with inspectional methods and making use of all of the various recognized testing procedures, it seems appropriate to admit frankly that there are no short-cut methods or trick devices by which an inspector can detect any flaws beyond surface conditions by ordinary visual examination. Under the most favorable circumstances the best that any inspector of welding can hope to accomplish is conscientiously to carry out a thoroughly planned procedure making use of all the applicable methods of testing appropriate to the job or as called for in the specifications. After having done this and having throughout exercised good sound engineering judgment and an unbiased interpretation of requirements and testing results in a spirit of cooperation, the inspector may then feel that the appropriate quality of product has been attained.

Even though all available testing procedures are at best merely random checks against a given standard, it must not be assumed that such methods are peculiar to the welding practice, because all testing and all inspection is based on one principle—sampling methods based on probabilities.

It is important for inspection personnel to approach each new project with the idea that a satisfactory schedule of activity or inspectional procedure is just as necessary in that work as it is in the design, the qualification procedures, the techniques of welding, the supervision and control of the work and everything that has been said in the foregoing. Typical of what should be done in each such case is given in the following outline of the general application of the three main subdivisions of inspection procedure:

A. Procedure Inspection
   1. Prior to Welding:
      (*a*) Base Metal Quality:
         Chemical Characteristics
         Physical Characteristics
         Flatness or Form
      (*b*) Base Metal Defects:
         Cracks
         Laminations
         Blisters
         Other Surface Irregularities
      (*c*) Fitting or Joint Fit-Up:
         Edge Preparation
         Root Opening
         Cleanliness
         Tacking and Backing
      (*d*) Fabrication and Assembly:
         Templates
         Jigs and Bracing
         Special Setups
         Dimensions
   2. During Welding:
      (*a*) Preheat and Interpass Temperature
      (*b*) Root Passes
      (*c*) Preparation for Backing Pass
      (*d*) Welding Backing Pass
      (*e*) Cleaning Between Passes
      (*f*) Appearance Check
      (*g*) Check with or Variations from Approved Procedure
   3. After Welding:
      (*a*) Post Heat, if any
      (*b*) Recheck Corrective Work
      (*c*) Finish Peening, if any, but only after Acceptance Testing Requirements are satisfied

B. Acceptance Inspection
   1. Special Requirements (Proof Testing):
      (*a*) Codes or Regulations such as Hydrostatic or Pressure Testing to develop all defects not otherwise readily detectable
   2. Destructive Testing:
      (*a*) Chemical
      (*b*) Physical
      (*c*) Metallographic
   3. Nondestructive Testing:
      (*a*) Visual Inspection
         Surface Appearance
         Dimensional Check
         Check with Standard Shape
      (*b*) Examination for Surface Defects:

Penetrating Oil analysis
Magnetic Particle analysis
(c) Examination for Internal Defects:
Radiography

C. Inspection of Corrective Welding
1. Preparation for Welding
2. Supervision During Welding
3. Inspection After Welding

A wise inspector will build up mutual confidence with the inspectors and supervisors of the manufacturer to the end that they might collaborate smoothly in such an important undertaking as that implied by the foregoing outline. This course would be followed unconsciously by an experienced inspector and it is of such tremendous importance that it leads one to amplify some of the published qualifications for a welding inspector. For example, if the previous statement be true then obviously it would be better to give an experienced inspector training in the fundamentals of welding than it would be to start with an expert in welding and hope by brief training to make him a welding inspector as is the custom. In this connection, it is important to emphasize the fact that an experienced inspector's attitude commands respect and since most of his decisions are of necessity called for in borderline cases there will be no lack of confidence in his careful, impartial, consistent and impersonal judgment.

While the experienced inspector should exhibit infinite patience and not refuse to listen to the views of others nor be argumentative he should nevertheless be firm in his convictions. He will at all times show intelligent understanding of the requirements he is attempting to administer. Obviously, he must study continually every detail of the job in hand and its functioning in the general scheme of things. To such an extent must he follow this practice that he shall even be in a position to find it possible to suggest improvements in some of the details given him in design and even some of the standards presented to him by way of Code specifications.

Thoreau is said to have philosophized "Our life is frittered away in detail," but that may explain his seeking a life of seclusion to avoid reality. The older philosophy, the very contrary of Thoreau, will be found more realistic because it cautions us, "To take care of the little details and the big things will take care of themselves."

References

A2.0-47 Standard Welding Symbols

The American Welding Society's standard symbols for denoting welds made by any welding process on engineering drawings. Contains detailed rules for using the symbols and sketches showing typical applications. An abridgment of the symbols and rules for their use are given on a single sheet suitable for posting. 68 pages.

A3.0-42 Definitions of Welding Terms and Master Chart of Welding Processes

The standard definitions of welding terms of the American Welding Society, illustrated by numerous sketches. Also includes a chart showing the subdivisions of the various welding processes, namely: arc welding, gas welding, resistance welding, thermit welding, forge welding and brazing. 32 pages.

A4.0-42 Standard Methods for Mechanical Testing of Welds

The standard methods for making mechanical tests of welds, including tests for density, soundness, tensile strength, shear strength and ductility (bend tests). The tests apply to base metal, weld metal, groove-welded joints and fillet-welded joints. Includes sketches of the specimens and describes the methods of conducting the tests and evaluating the results. (With 1945 addition.) 25 pages.

A5.1-45T Specifications for Iron and Steel Arc-Welding Electrodes (Tentative)

A specification covering dimensions, characteristics and properties of 28 different classifications of lightly coated and covered arc-welding electrodes for the welding of carbon and low-alloy steels. An appendix to the specifications, entitled "Guide to A.W.S.-A.S.T.M. Classification of Iron and Steel Arc-Welding Electrodes," describes the system of electrode classification and serves as a guide to the selection of the most suitable electrode classification for a given application. 19 pages.

B1.1-45 Inspection Handbook for Manual Metal Arc Welding (Emergency Standard)

This handbook sets forth the general duties and responsibilities of the inspector in performing inspection of weldments produced by the metal-arc welding process. It also serves as a convenient source of information relative to inspection of welding. Topics covered include: requirements for a welding inspector, duties of a welding inspector; welding procedure specifications, qualification of welding procedures and operators, heat treating operations; weldment defects, methods of testing welds; visual inspection, magnetic particle inspection; radiographic inspection. An appendix gives the standard A.W.S. definitions of terms related to metal-arc welding and radiographic inspection. 156 pages.

B2.1-45 Code of Minimum Requirements for Instruction of Welding Operators: Part A—Arc Welding of Steel

A standard course for the instruction of arc-welding operators, covering: equipment and facilities of the school, qualification and duties of the instructor, instruction in welding practice, instruction in welding theory and final tests. The code includes nine appendices of suggested and recommended material, as follows: suggested accessory equipment for welding schools, recommended design of positioning equipment, recommended designs of testing apparatus and their application, recommended safety rules, welding electrodes, suggested arc-welding exercises, suggested form of student progress chart, recommended form for record card, annotated selected bibliography of publications relating to arc-welding instruction. 83 pages.

B3.0-41T Standard Qualification Procedure (Tentative)

The standard methods of qualifying welding procedures and welding operators, intended principally for adoption by code-writing bodies. The *Standard Qualification Procedure* has been incorporated in

practically all of the more important codes and specifications on welding. 39 pages.

D1.0-46 Standard Code for Arc and Gas Welding in Building Construction

A complete set of regulations recommended by the Society for adoption by municipalities as part of their building code, to cover the application of arc and gas welding in building construction. The provisions of the code govern materials, design, permissible unit stresses, workmanship and inspection. Included are appendices on definition, welding symbols, welded joints, qualifications of welding operators and procedures and illustrations of acceptable and defective weld profiles. 68 pages, indexed.

D2.0-46 Standard Specifications for Welded Highway and Railway Bridges

These specifications are intended to supplement the general specifications for welded highway and railway bridges and cover welding standards for design, fabrication and repair. Included are appendices on unit stresses for welded design, definitions of welding terms, welding symbols, qualification of welding operators and procedures, and base metal specification requirements. 102 pages, indexed.

D3.1-41 Report on Thermal Stresses and Shrinkage in Welded Ship Construction

A report on an investigation of the general problem of thermal stresses and shrinkage in welded ship construction, including a description of the principal methods employed to minimize shrinkage and the effects of thermal stresses. 12 pages.

D3.2-44T Structural Failures in Welded Ship Construction (Tentative)

A report discussing the factors causing failures in welded ship construction and some suggested means for their control. This report is an extension of the principles set forth in the report "Thermal Stresses and Shrinkage in Welded Ship Construction," and has been prepared to assist the shipbuilding industry in its welding problems until extended studies are completed and fully reported. 9 pages.

D3.3-44 Rules for Fusion Welding Piping in Marine Construction

A revised issue of the Standard first published in 1935 covering the welding of low-carbon (0.35% max.) steel marine piping. Topics include: qualification of welding procedures, qualification of welding operators, design, layout and dimensions of piping, allowable types of joint, preheating, stress-relieving, radiographic tests, hydrostatic tests. 4 pages.

D4.0-44T Weldability Standards for Alternate Aircraft Steels (Tentative)

A series of tests for comparing the weldability of proposed alternate steels with standard aircraft steels. Included are the tee-bend test; transverse butt-joint tension test of plate, sheet and tubing; welded double-tube triangle test. Test specifications include test plate dimensions, filler metal sizes, preheating and welding procedures as well as the methods of testing. The test methods described are applicable to both arc and gas welding, as indicated, and were selected not only for their reliability but also for their ease of performance in the usual aircraft plant. 14 pages.

D5.1-47 Rules for Field Welding of Steel Storage Tanks

Standard requirements covering the welded construction of bulk storage tanks for holding liquids at substantially atmospheric pressure. The Rules cover materials, design, workmanship, inspection and testing. 19 pages.

D5.2-43 A.W.W.A.-A.W.S. Standard Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs

These specifications prescribe minimum requirements as to the design, fabrication and erection of elevated steel water tank, standpipe and reservoir structures of either welded or riveted construction. The requirements relative to welding are identical to the Rules for Field Welding of Steel Storage Tanks. 35 pages.

D6.0-46T A.W.W.A.-A.W.S. Standard Specifications for Field Welding of Steel Water Pipe Joints (Tentative)

These specifications prescribe minimum requirements for the fabrication of welded steel water pipe joints. Included are requirements for filler metal, equipment, inspection, qualification of welding procedures and welding operators, joint design and welding design details as well as methods of sectioning for testing welded pipe joints and repair of welds. 12 pages.

E3 Guide to Weldability of Steels. 1943

A proposed system of determining the effect of welding procedures upon the ductility of the heated zone adjacent to the weld in plain carbon and alloy steels. This book presents a method of predetermining and handling the loss of ductility in the base metal next to a weld. 89 pages.

Welding Handbook, 1942 Edition

A complete reference book and text on all welding processes, the welding of various metals and the use of welding in different industries. This is a special reprinting for distribution until new, 1948 edition is available. 1593 pages, cloth bound.

Welding Metallurgy. By O. H. Henry and G. E. Claussen. 1940

A fundamental text on metallurgy and metallography with particular reference to the metallurgical effects of welding. Easily understood. Illustrated with sketches, tables, graphs and photomicrographs. 359 pages, cloth bound.

Practical Design of Welded Steel Structures. By H. M. Priest. 1943

A concise discussion of the considerations involved in the design of welded steel structures. Includes sketches of typical details and charts for determining amount of welding required for various connections. 155 pages, cloth bound.

Procedure Handbook of Arc Welding Design and Practice (Lincoln Electric Co.). Eighth Edition

Manual of Design for Arc Welded Steel Structures. By La Motte Grover. (Air Reduction Sales Co.)

How to Weld 29 Metals. By C. H. Jennings (Westinghouse)

Flexarc Engineering Data Book (Westinghouse Electric Corp., Buffalo, N. Y.). First Edition, 1946

Prolonging Copper-Tungsten Electrode Tip Life

Careful control in manufacture of resistance welding electrodes and their inspection by the purchaser insure better service and longer tip life

by D. J. Rahn

THE blessings that are American were forcefully emphasized recently while talking to a representative of a French manufacturer of resistance-welding equipment. The Frenchman kept steering the conversation into the paths of electrode cooling, refrigerants, water supply and minimum currents required for maximum penetration. It developed that his intense interest in American methods of die cooling was motivated by the fact that in France, deprived of chromium, beryllium, tungsten, etc., practically all resistance welding employs electrodes of pure copper.

If we were forced to accept such limitations it would place this form of fabrication back twenty-five years. Even prior to that various elements had been alloyed with copper for welding-contact purposes. Today the addition of cobalt, beryllium, chromium, nickel and others has resulted in materials of satisfactory current-carrying properties with high yield strength and high temperature at which it resists deformation.

Outstanding progress, too, has been made toward better contact material for special welding applications with the introduction of powder metallurgy. This new science is applied to the welding industry by electrode manufacturers employing compounds containing copper powder and such materials as powdered tungsten, molybdenum or their carbides, utilizing the high melting point of the hard materials with the high thermal and electrical conductivity of copper. Therefore, we slowly approach that probably never-to-be-attained theoretical ideal—an electrode combining the electrical conductivity of silver with the compressive strength of tool steel.

As higher tensile and heavier gage stock is constantly being welded by the resistance method and heavier burdens placed on the electrodes, in the interest of economy fabricators are giving more thought to two phases of their electrode question. First, a strict laboratory inspection of the purchased material and, second, rigid control of shop practices and engineering setups.

The copper metal powder tip material, which we are considering here and attempting to point out conditions and practices which affect economy, is the one most commonly used, the copper-tungsten mixture. The most widely accepted method of manufacturing this product is to first press the copper and tungsten powder into bars and presinter them. Next, the bars are heated by their own resistance by passing current through them until the center has nearly reached the melting point. This may reach a heat of from 4500 to 5800° F. The bars are then pressed hot in a hydrogen atmosphere until the desired compact is attained. The various heat-treatable alloys of RWMA Group A, which in many applications are superior to RWMA Group B (the sintered powders), are not being underrated here; however, where an extremely high working temperature is necessary, though never ideal, and tool design and clearance limitations forbid a solid, removable tip, the copper-tungsten sintered material brazed to a suitable backing-up member is the acceptable answer.

There are few companies in the United States engaged in the manufacture of sintered copper materials. Their job is definitely a critical one. Those the writer has visited are thoroughly conscious of the nature of their product and exert extreme control throughout the process of manufacture, from a rigid inspection of particle size and purity of the powder through pressure and temperature during sintering. However, it is no reflection on the integrity of the vendor for the purchaser to check thoroughly the quality of this expensive item before it is placed on the job. Shops lacking laboratory testing equipment may obtain this service from an independent testing organization.

A check of this sort to determine the properties of the tip material is beneficial in two ways. It not only decreases costs by rejection of all material not falling within acceptable standards but, by acquainting the manufacturer with the fact that close check is made, results in his producing—or at least delivering to the critical customer—a superior, more uniform product. Incidentally, tip material is usually purchased to conform to RWMA standards as to proportional limit and tensile strength, conductivity and hardness. The writer has observed an increase of hardness from 95 Rockwell B, on material received before rigid inspection, to 105.5 Rockwell B after the manufacturer was made familiar with the fact that a 100% check was made on his product for hardness, particle size, distribution and conductivity.

The photomicrographs in Figs. 1 and 2 illustrate the advantage of close check by the customer. Both specimens were received in a single shipment. They were cut from briquettes of copper-tungsten (RWMA Group B, Class 11) $^3/_4$ in. diameter by 8 in. long. The tungsten was etched and the magnification is 1500 ×. The hardness of the specimen shown in Fig. 1 was 105 Rockwell B. It is small grained with well interlocking particles and had a conductivity of 29% of copper. The specimen shown in Fig. 2, in contrast, was 95–97 Rockwell B, uneven and low in hardness, with large, poorly distributed tungsten particles. The conductivity of that in Fig. 2 was 27% of copper. Both were acceptable to RWMA standards and fell within the manufacturer's specifications for this alloy; however, a substantiating check on the production floor proved the specimen in Fig. 1 much superior to that in Fig. 2. Specimen slugs, cut from the same bars adjacent to the specimens used in the micro-examination, were used on the same production job. The harder, closer grained specimen in Fig. 1 remained in operation nine days, 3 shifts per day, while that in Fig. 2 remained in operation only four days of three shifts each and one additional shift on the fifth day. Both tips fabricated identical pile-ups. Machine settings were unchanged and the same three operators performed the work. The study was taken up with the supplier and resulted in his delivery in subsequent shipments of a more uniform, harder product.

It should not be implied from the foregoing that hardness is necessarily relative to particle size. The compactness and composition governs this, although small,

Mrs. Rahn is the Metallographer at the Rail-car division of The Budd Co., Phila., Pa.

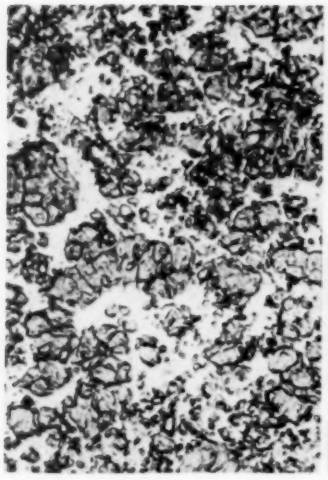


Fig. 1 Small grained, well interlocking particles of copper-tungsten. Gave excellent service. Tungsten etched. 1500 ×

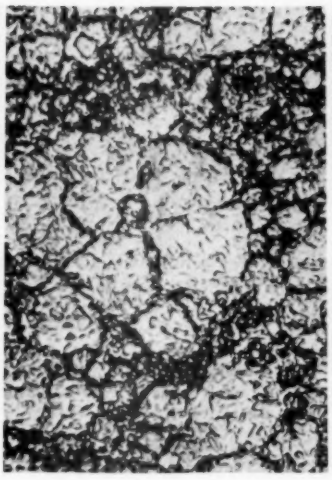


Fig. 2 Large tungsten particles poorly distributed. A life test proved material unsatisfactory. Tungsten etched. 1500 ×

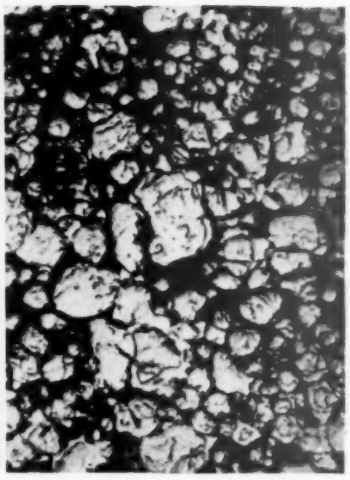


Fig. 3 Tungsten particles large and not compact. Unsatisfactory service. The copper was etched. 1500 ×

tightly cemented particles free from porosity and inclusions give the best service. Neither should it be implied that the harder the tip material, the longer its life. Copper-tungsten metal powder products are lacking in ductility and this brittleness increases with use. In heavy welding multipile-ups of, say, three pieces of 0.200 high tensile 18–8, where a 1-in. diameter tip is used, the softer RWMA Group B, Class 10, is often superior to the harder Class 12. Class 10 material seems better able to resist deformation and resulting tip cracking. In these heavy jobs, the necessary high electrode pressure makes ductility of the tip material extremely important. However, when thinner material is being welded and consequently lower tip pressure used the writer has observed that the harder tips are much more economical. For example, a $^1/_2$-in. tip faced with copper-tungsten with a Rockwell hardness of B94–96 lasted for one shift while those of B 102–104 remained on the tool $2^1/_2$ shifts under identical conditions.

Inspection, compromising microstructure study, hardness and conductivity checks pay off, too, in the selection of new vendors of tip materials. Manufacturers are constantly making claims for new or improved products and new manufacturers (or at least new vendors) are presenting their wares to the electrode-consuming public. Such a case is illustrated in Figs. 3 and 4. They are photomicrographs, at 1500 × magnification, of a sample submitted by a new vendor of a product of which phenomenal claims were made. Figures 3 and 4 are the same specimen, Fig. 3 etched to reveal the copper and Fig. 4 the tungsten. The metal powders are large and poorly distributed and because of this the customer was sceptical of the material despite the fact that hardness and conductivity were satisfactory according to RWMA specifications. A life test was run on this material in the shop, and the laboratory theory that poor distribution of the powder particles and variation in size, shown to exist in the microstructure, mean unsatisfactory tip life was substantiated. In use, marked mushrooming occurred. It required constant dressing and was removed from service after 1500 welds.

Figure 5 is a photomicrograph at 1500 × of copper-tungsten which gave excellent service.

Thus, an attempt has been made to emphasize the importance of strict control of accepted material by close check on hardness, conductivity and microstructure.

In considering the prolongation of tip life, the purchase of a satisfactory material is only an introduction. Through shop abuse the finest electrode can be rendered worthless. Especially in the sintered products must the variables be controlled to exactness. It should be written in letters a mile high "Keep Them Cool."

Copper-tungsten breaks down at high temperature and the copper constituent

Fig. 4 Same as Fig. 3, except the tungsten was etched. 1500 ×

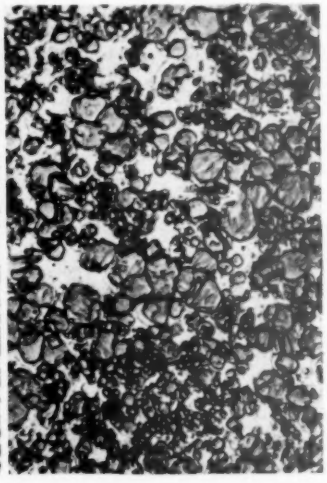


Fig. 5 The microstructure of satisfactory copper-tungsten. Tungsten etched. 1500 ×

diffuses causing either mushrooming or depositing of copper on the stock being welded. This material is brittle at best and when part of its copper has been removed ductility is even less. Cracking from the edges toward the center or center cracking is the result.

Because of this brittleness it must have a hard base, and hence the backing-up material must be firm. Excess heating here, too, alters the properties of this copper alloy to a point where it is unable to take the stress of the constant hammering of the harder facing material during the weld. When this occurs the backing-up material deforms, and the harder copper-tungsten, lacking a firm seat, cracks. Figure 6 is a macrophotograph of a typical electrode failure due to weak backing-up material. Center cracking usually indicates this, while cracking from the edge toward the center is the result of subjecting the electrode to a higher working temperature than the material will allow.

Keep the electrodes cool by adequate internal water cooling, and use the largest diameter water hole practical. For example, a tip $^7/_8$ in. in diameter, 2 in. long overall made of a Group A, Class 2 copper alloy, faced with Group B, Class 11 copper-tungsten, should carry a water hole of not less than $^1/_2$ in. diameter, $1^1/_2$ in. deep. The remaining $^1/_2$ in. includes $^1/_4$ in. copper-tungsten. The end of the drill point should not be closer to the copper-tungsten than $^1/_4$ in. (in this case) due to the necessity of a strong backing-up face discussed above.

It is a great temptation for maintenance men to braze a much longer length of copper-tungsten to the tool than is necessary for immediate reaction, as the longer the piece the less frequent the need for replacement. When an excessive amount of sintered material is applied it not only decreases the conductivity of the tool but places the water chamber farther away than necessary from the contact surface.

Keep the tip material cool while brazing. Dies of the screw in type, or removable tapers, offer a distinct advantage in that they may be brought back to the shop to be retipped. Stationary types must be brazed on the job. In a maintenance shop conditions are more readily controlled and induction heating may be employed; however, a skilled operator equipped with a portable tank can flame solder the copper-tungsten to its backing-up member quite efficiently. In all brazing both material to be applied and material on which it is applied must be kept at the lowest possible temperature.

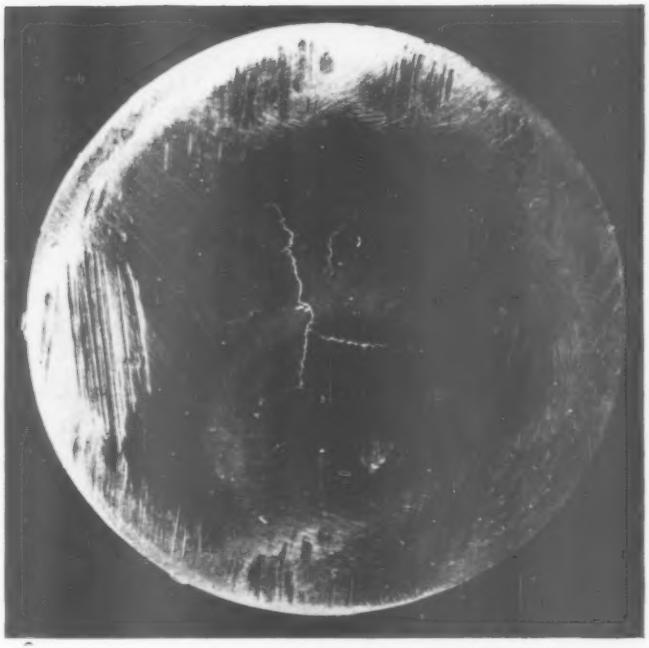


Fig. 6 Macrophotograph of an electrode which cracked due to weak backing-up material. 3.15 ×

The writer finds the following technique for brazing copper-tungsten to a Group A alloy shank satisfactory:

First, remove the old slug with a minimum of heating of the tool.

Clean the backing-up member where the sintered material is to be applied and check for flatness.

Check the flatness and cleanliness of the slug to be applied.

Heat slug and tin it.

Heat backing-up member, apply brazing flux.

Place slug in position and align it.

Reheat if necessary.

Disconnect air pressure on the machine, then apply the slight pressure of the weight of the tool by allowing the electrodes to contact. The weight is usually sufficient to seat the joint.

Dress sides to remove excess flux.

Dress dies to required radius.

In heating the slug and backing-up member, care should be exercised in keeping the two materials below the red-glow heat.

In conclusion it may not be pedantic or hackneyed to recall some recommendations which aid materially in increasing tip life although they are as old as the resistance-welding industry.

Never apply the welding pressure with a hammer blow. Easy pressure allows the tip to receive the strain without deformation.

Never seal the base of a taper with a material low in conductivity (as white lead). Use a grease manufactured for this purpose, or better still have a good fit.

Do not compensate for mislignment of material by increasing tip force.

Copper-tungsten is an expensive product, expensive to manufacture and expensive to the customer. Economy may be achieved by handling it with the same respect we give silver or gold or the diamond point on the Rockwell machine. It is hoped that some economy may be effected by a study of the product's microstructure and application on the job.

The American Welding Society

Its purposes, objectives and methods of operation

by J. G. Magrath

WEBSTER, among other definitions, provides as a meaning of the word "society," the following: "The relationship of men to one another when associated; . . . .a body of persons united for the promotion of a sound object, either literary, scientific, political, religious, benevolent, convivial or the like; . . . an association for mutual profit, pleasure or usefulness."

Aside from the political and religious aspects the AMERICAN WELDING SOCIETY certainly aspires to and, in results, succeeds in achieving the greater number of these services to its members and to industry.

During the First World War, in order to consolidate the then available knowledge in welding, the Emergency Fleet Corp. formed a "Welding Committee" unit. After that war it was indicated that an organization was required which would foster and encourage the welding developments resulting from the activities of that Welding Committee. As a result the AMERICAN WELDING SOCIETY was formed in 1919 with a total membership of 217. Today it is an organization of invididuals and of various company representatives, either users, manufacturers or sellers, and comprising a membership of 7400 at the end of 1947.

In 1932 the SOCIETY was incorporated under the membership corporation law of the State of New York and the purposes for which it was formed were defined to be limited to educational, scientific and literary purposes and not for any business or profit-making. In view of the frequent requests for the SOCIETY's assumption of varied activities it is important to recognize the limitations of its license for operation.

Membership in the AMERICAN WELDING SOCIETY is open to anyone interested in welding by any process, gas cutting, brazing or the heating applications, or any of the processes allied with welding, as well as to all those concerned with the efficient application of the art and science of welding and its allied processes, and the industrial acceptance thereof.

The objectives of the SOCIETY may be summed in one sentence: To advance the art and science of welding. More specifically they can be detailed as follows:

(*a*) To encourage the development of the art and science of welding through improvement in present applications and expansion of its uses into new fields, and to develop technical and ethical standards for the welding industry.

(*b*) To provide a means for the interchange of knowledge and experience to aid in the solution of the problems of the welding art—technical, ethical and commercial—through cooperative effort.

(*c*) To promote a better understanding among users, sellers, manufacturers and scientists in the welding field, and to foster a spirit of cooperation for the common good.

(*d*) To collect and make available authentic, useful and up-to-date information on welding and the allied processes, and to serve as the authoritative source of such information for users, sellers and manufacturers in the welding field, engineering societies and legislative bodies.

(*e*) To be the agent of industry in cooperative research on important technical welding and allied process problems, and to serve as a common spokesman of the welding industry in matters pertaining to its welfare.

To accomplish these purposes and objectives the SOCIETY has developed, for the serving of its members and industry, a national organization that is comparable in size to that of many large corporations, excepting that this organization is staffed by men who voluntarily, without charge, contribute their time and efforts.

Localized affairs are in the hands of fifty-two AMERICAN WELDING SOCIETY "Sections" strategically located in most industrial activities areas. Expansion of "section coverage" is now under way and it is possible that these may soon number sixty-five. In addition a number of the Sections will be expanding their activity to comprehend sub-Sections or "Divisions." (These will be discussed later.)

A Section's management affairs are conducted by eight to eighteen elected Section Officers, the number depending upon the size of the Section. These are a Chairman, a First and a Second Vice-Chairman, each elected for a one-year term (maximum 2 terms);

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Lecture presented at the National Welding Dealers Association Convention in St. Louis, Mo., May 21, 1948.

a Secretary and a Treasurer each elected for a three-year term (eligible for re-election); and five to thirteen Board Members each elected for either a three- or a one- and a two-year term. All have a vote and serve without charge. There are of course, in addition, drawn from the Section Membership, many persons serving on the various Section Committees as Chairmen and Members.

National management affairs are conducted by (at this date) twenty-seven elected National Officers. These are a President, a First and a Second Vice-President, each elected for a one-year term (maximum 2 terms); seven District Vice-Presidents, each elected for a two-year term (maximum 2 terms); a Treasurer elected for a three-year term (eligible for re-election); sixteen Directors at Large, each elected for a three year term; and one Honorary Director. All serve without charge and all vote.

There are two paid National Officers: (*a*) the Executive Secretary and (*b*) the Secretary, who is also the Assistant Treasurer. Both are appointed by the Board of Directors for a one-year term and do not vote.

In the National Headquarters Staff are (*a*) the Editor of THE WELDING JOURNAL (who is also Director of the Welding Research Council), (*b*) the Technical Secretary, who is also Editor of the *Welding Handbook*, (*c*) the Service Manager and (*d*) sixteen bookkeeping, editorial, clerical and stenographic assistants. All are paid and none vote.

The various management activities are served by eighteen Standing Committees, comprised of approximately 200 Industrial Executive Members, who voluntarily contribute their time and effort. All vote. These activities comprehend financial, membership, admissions, publications, programs, by-laws, education, awards, permanent funds, public relations, publicity, conventions, etc.

The SOCIETY's many Technical Activities are provided by over one hundred Technical Committees and subcommittees manned by over four hundred industrial, educational and scientific authorities throughout the country who, voluntarily, contribute much time and much effort, all of whom vote.

A summation of the aforegoing tells us "who" is the AMERICAN WELDING SOCIETY.

1. It is a non-profit education organization.
2. It is supported by 7400 paying and voting Members.
3. It is technically guided by 400 nonpaid voting industrial, educational and scientific authorities.
4. Its management is guided by 200 nonpaid voting industrial executive Committee Members.
5. It is managed sectionally by 700 nonpaid voting industrial executive elected Section Officers.
6. It is managed nationally by 27 nonpaid voting industrial executive elected National Officers.
7. It is serviced by 21 paid nonvoting individuals.

A survey in 1945 provided an indication of the industrial occupational status of the AMERICAN WELDING SOCIETY's membership. Its breakdown is serving as a guide for the direction in which the Society will beam its activities for increasing its present total membership of 7400 to a potential 15,000. Occupationally, the membership comprised:

28% Production
- 14.5% Managers-Superintendents
- 12.5% Foremen-Supervisors
- 1.0% Inspectors-Motor Mechanics

29% Engineering
- 27% Engineers of various classifications
- 2% Designers and Draftsmen

9% Highly Technical
- 2% Scientific
- 3% Metallurgical
- 2% Technical
- 2% Educational

8% Executive
- Administration and Purchasing

8% Sales
- Sales-Advertising-Publishing

15% Welding Group
- 8% Welding Operators
- 7% Welding Contractors

3% Miscellaneous Classifications

100%

Unlike most engineering societies whose membership is drawn almost entirely from the technical professions, the Membership of the AMERICAN WELDING SOCIETY, occupationally, is of widely varied origin. As a result it is difficult to provide a universal answer in all activities which will satisfy all at all times.

Up until about the year 1919 welding was in the order of a good trick if one could do it. During the period between 1919 and 1926 it became an art; the greater knowledge of application and use being possessed by the artisan welder. Starting approximately in 1926 the engineer and metallurgist began to study intensively the welders "art" and increasingly substituted scientific knowledge for the welders "know-how." Thus, welding became an art and a science.

Doubtlessly the greater future for welding will be found in the realm of science. It has been in this field that the efforts of the AMERICAN WELDING SOCIETY have been rightly directed. Our SOCIETY and its activities and publications have received national and international recognition for having contributed the most in this field. It will continue its activities in that direction and will seek to supplement its present vast warehouse of welding knowledge with even greater scientific formula and procedure as quickly as the increasing efforts of the industry's technical minds provide that material.

But it does not lose sight of the present, a period in which welding is still an art and a science, in that our engineering procedures and metallurgical formulas for welding are still greatly dependent for success in

application upon the skill and intelligent thinking of the artisan welder.

Recognizing that approximately one-third of its present Membership and that at least an equal portion of its potential Membership is in the Production Group which includes Foremen, Inspectors, Instructors and Operators of the artisan standard, it is seeking a pattern that will permit this essential and important occupational group to utilize its many educational benefits. It recognizes that to effect this program it must present these benefits in an acceptable, understandable manner. Academic theory must be transposed into practical application and concrete example; laboratorial terminology must be translated into shop and field words; algebraic formula must be reduced to mechanic's arithmetic; and "volume" must be reduced to "essence."

Such will not be an easy task and the path is not wholly clear. But our SOCIETY observes the need and is seeking the answer within the range of practical economics. The AMERICAN WELDING SOCIETY, as is indicated by the high percentage in the Technical, Metallurgical and Research Groups, has most successfully provided the required benefits desirable to these groups. It will continue to serve them as in the past but will strive to extend the scope of those benefits to cover the requirements of other industrial groups as well.

The AMERICAN WELDING SOCIETY benefits directly every person and organization associated with welding and the allied processes, whether they be users, sellers or manufacturers. Knowledge, or increase in knowledge, which makes possible the application of welding in a new field, or makes applications in older fields safer as well as more efficient, means more economies for the users of welded products. Standardization and quality in mass production are almost synonymous. It is in this line of activity that the SOCIETY has been extremely helpful. Its codes and standards are universally accepted as authoritative. They have enabled users and industry to save hundreds of thousands of dollars.

Of particular value to the Welding Supply Dealer is the SOCIETY's local Section activities. In each of the important industrial centers of the States, Members of the SOCIETY join in meetings on the average of eight times each year, or more. Industrial executives and leaders of these communities voluntarily contribute their time and effort to arrange programs of interest and value to local industry. Speakers of national recognition are secured and the latest developments in the industry are brought to the local doorstep for all to gain therefrom. The Section Meeting provides the Welding Supply Dealer and his personnel the opportunity to meet local and distant industrial leaders in an atmosphere of good fellowship, community spirit, and educational exposure.

Every industrial community or center of welding activity needs either an AMERICAN WELDING SOCIETY Section or Division utility. Such an activity requires an investment of interest, moral as well as financial. But it is a sound investment as it is in the nature of industrial and commercial educational insurance to all whose interests are associated wholly or partly in welding.

Where AMERICAN WELDING SOCIETY Sections are now in operation the Welding Supply Dealer and his personnel should become acquainted with the local Section Officers and join the Section. They want and need the dealers help. They want to know what types of program would be the most beneficial to all.

In areas where, at present, there is no Section or Division activity, the Welding Supply Dealers will benefit greatly by joining in a mutally cooperative effort of sponsoring and assisting in the formation of one. The National Headquarters of the AMERICAN WELDING SOCIETY at 33 W. 39th St., New York, 18, N. Y., will be pleased to provide all information regarding present Section activity and the formation of new Sections or Divisions, and assist toward formation.

Equally as much as the Welding Industry does the AMERICAN WELDING SOCIETY belong to the Welding Supply Dealer. It is his Industry and his SOCIETY.

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Electric Heating, Industrial. What's New in Induction Heat-

(Continued on page 461)

How to Qualify Your Welders

Here's the answer to your questions on welding operator qualification. Of interest to the welder and to the welding engineer

by Simon A. Greenberg

REQUESTS are received almost daily for information on the steps to be taken in qualifying welders under the various codes. It is hoped that the following article will satisfy most of the questions which arise and clarify the misunderstandings regarding welding operator qualification.

Through the efforts of the A.W.S. Committee on Standard Qualification Procedure, a simple comparatively inexpensive test has been established for the qualification of welding operators. This test is prescribed in the AMERICAN WELDING SOCIETY'S *Standard Qualification Procedure* and is commonly referred to as the "guided-bend test."

Briefly, here is a summary of the qualification requirements for welding operators.

GROOVE WELDS (BUTT WELDS)

(*a*) Where an operator is to weld on material up to and including 3/4 in. thick, he is required to weld a joint between two 3/8-in. plates, about 6 3/4 in. long minimum. Such a joint must be welded in each of the positions, i.e., flat, vertical, horizontal and overhead, in which he is to be qualified; however, qualification in any other position automatically includes qualification in the flat position so that a test plate need not be made in the flat position. On this basis, for qualification as an all-position welder, the test must be made in the horizontal, vertical and overhead positions.

If the operator is to weld on pipe, he should be qualified by welding pipe joints.

In any case, after the joint has been welded, one root-bend and one face-bend specimen are removed (see Tables 1 and 2 and Figs. 1 and 2) and tested in the guided-bend test jig (see Fig. 3).

(*b*) Where an operator is to weld on material thicker than 3/4 in. the same procedure will apply except that the plate used must be of the maximum thickness to be welded or 1 in. (either is acceptable). Further, instead of face- and root-bend specimens, side-bend specimens (see Fig. 4) are used. Testing in the guided-bend-test jig is the same.

Qualification to weld the thicker (3/4 in. or more) material automatically covers qualification to weld

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Reprint of this information available on request.

Table 1—Operator Qualification Tests for Groove Welds in Plate

Maximum thickness for which operator is to be qualified	*Thickness of material for test weld*	*Number and type of tests required* Root-bend. (see Fig. 1)	Face-bend. (see Fig. 1)	Side-bend. (see Fig. 4)
Up to and including 3/4 in.	3/8 in.	1	1	..
Over 3/4 in.	Maximum, but need not exceed 1 in.	..	..	2

Table 2—Operator Qualification Tests for Groove Welds in Pipe

Maximum thickness for which operator is to be qualified	*Thickness of material for test weld*	*Number and type of tests required* Root-bend. (see Fig. 2)	Face-bend. (see Fig. 2)	Side-bend. (see Fig. 4)
Up to and including 3/4 in.	3/8 in.	2	2	..
Over 3/4 in.	Maximum, but need not exceed 1 in.	..	..	4

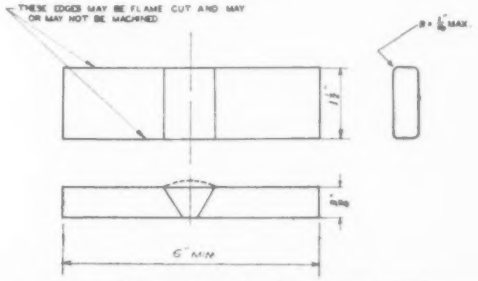


Fig. 1 Face- and root-bend specimens (plate)

Note: **Weld reinforcement and backing strip, if any, shall be removed flush with the surface of the specimen. If a recessed strip is used this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the strip, except that in such cases the thickness of the finished specimen shall be that specified above.**

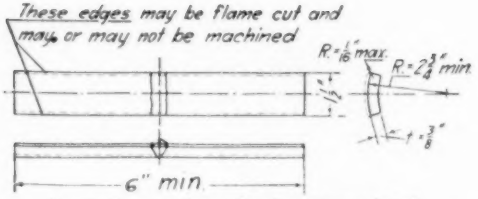


Fig. 2 Face- and root-bend specimens (pipe)

Note: Weld reinforcement and backing ring, if any, shall be removed flush with the surface of the specimen. If a recessed ring is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the ring, except that in such cases the thickness of the finished specimen shall be that specified above.

the thinner (less than 3/8-in.) material so that only one set of tests need be made.

FILLET WELDS

For qualification to weld fillet welds an operator must deposit two fillet welds in a specially designed joint (see Fig. 5). These welds are to be of the maximum size used in fabrication but not over 3/8 in. One test assembly must be made in each position in which the operator is to be qualified except as follows:

A test weld made in the horizontal position qualifies an operator for welding in the flat and horizontal positions.

A test weld made in the vertical position qualifies an operator for welding in the flat, horizontal and vertical positions.

A test weld made in the overhead position qualifies an operator for welding in the flat, horizontal and overhead positions.

For qualification in all positions, an operator must make test welds in the vertical and overhead positions only.

Two specimens are removed from each joint and tested in the guided-bend test jig.

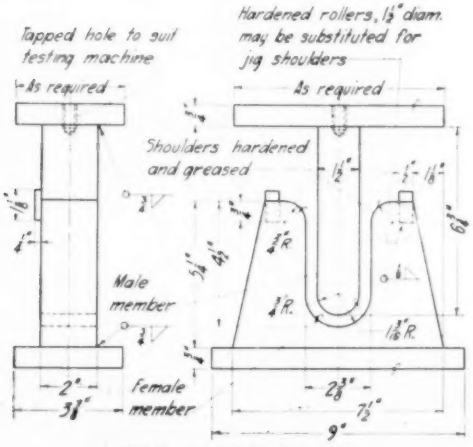
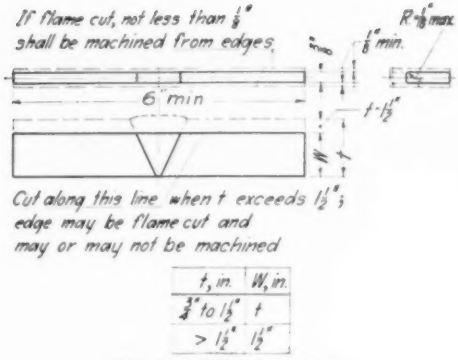


Fig. 3 Guided-bend test jig


If flame cut, not less than ⅛" shall be machined from edges.
R = ⅛" max.
⅛" min.
6" min
t - 1½"
W
t
Cut along this line when t exceeds 1½"; edge may be flame cut and may or may not be machined

t, in.	W, in.
¾" to 1½"	t
> 1½"	1½"

Fig. 4 Side-bend specimen

GUIDED-BEND TEST

The guided-bend test is performed by placing the specimen to be tested in the standard jig and forcing the plunger down (by any convenient means) upon the specimen and bending it to conform to the "U-shape" of the die member of the jig. It is then removed from the jig and examined for cracks, lack of root penetration, lack of fusion or other defects. If any open defect, measuring 1/8 in. in any direction is present, the specimen is not acceptable. In such cases the operator may be granted a retest immediately, consisting of two test welds of each type on which he failed, all of which shall pass. At the discretion of the inspector he may be required to submit evidence of further training or practice before being permitted to take a retest.

COMMENTS

Before the adoption of the guided-bend test, an operator was required to pass a tension test, a nick-break test and many other diverse special tests according to the individual ideas of one inspector or another. The guided-bend test was adopted when it was recog-

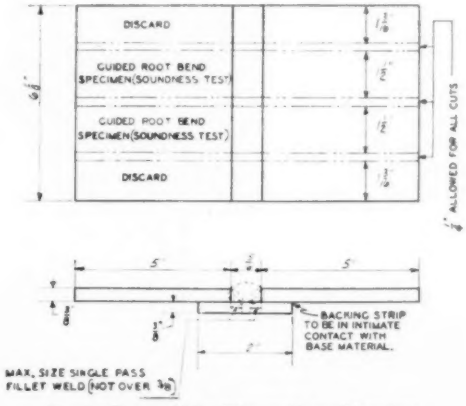


Fig. 5 Test weld for fillet-weld qualifications

nized that a welder should be required to demonstrate his ability to deposit a sound weld, and that such properties as tensile strength, elongation, corrosion resistance, etc., were controlled by the materials and welding procedures used, not by the ability of the operator.

Even more important, experience has shown that the guided-bend test is more searching than any of the older tests and that an operator may be capable of passing a tension test yet could not pass the guided-bend test whereas the reverse is not true.

From the standpoint of use, the guided-bend test is preferred because of the simple equipment required. Many of the shops make their own jigs although they can be bought. Also because it is a "go or no-go" test, no specially trained personnel are required to evaluate the results and the element of personal judgment is very largely eliminated.

Because of these reasons and because experience has shown the guided-bend test to be the most searching, the simplest to perform, the cheapest and the least time consuming, it has been almost universally adopted by code-writing bodies and by industry in general.

The following is a partial list of codes under which welders are qualified by test requirements conforming to the AMERICAN WELDING SOCIETY'S *Standard Qualification Procedure:*

A.W.S. Standard Code for Arc and Gas Welding in Building Construction (and municipalities in U. S. using this Code)

A.W.S. Standard Specifications for Welded Highway and Railway Bridges

A.W.S. Rules for Field Welding of Steel Storage Tanks

A.W.W.A.-A.W.S. Standard Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs

A.W.W.A.-A.W.S. Standard Specifications for Field Welding of Steel Water Pipe Joints

American Bureau of Shipping Regulations

U. S. Coast Guard Regulations

U. S. Navy Department Regulations

A.S.M.E. Boiler Code (including Unfired Pressure Vessels)

A.P.I.-A.S.M.E. Code for Unfired Pressure Vessels for Petroleum Liquids and Gases

Before attempting to qualify your welders study the *Standard Qualification Procedure* which contains the requirements for qualification in full detail and also tells when you must requalify your welders because of changes in your welding procedures or for other reasons. If you do not have a copy of the *Standard Qualification Procedure* contact the Technical Representative in your Local Section; he has a copy of this and every other A.W.S. standard. If you prefer write directly to A.W.S. headquarters.

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The Strength of Silver Alloy Brazed Joints

The strength of joints is influenced by the brazing alloy, its thickness, the strength of the metal joined, flux inclusions and the mechanical characteristics of the associated structure. Information also given on impact, fatigue and high temperature properties of brazed joints

by C. D. Coxe and A. M. Setapen

IN A TENSION test, the performances of a single piece of metal and of a brazed specimen may differ basically. The single piece of metal consists of one more or less uniform structure. The brazed assembly is comprised of the following elements: the two components being joined, the layer of brazing alloy and the interfaces. The strength of the assembly not only depends upon the properties of the individual elements, but also upon the mechanical restraints that the harder elements of the assembly may exert upon the softer ones.

The tensile strength of butt joints brazed with silver alloys is influenced by the following factors:

1. The degree to which the materials being joined are wet by and bonded to the brazing alloy.
2. The thickness of the brazing alloy layer in the joint itself.
3. The strength of metal or metals being joined—a very important consideration.
4. Amount of flux inclusions or voids in the joint.
5. The mechanical characteristics of the structure.

The strength of the brazing alloy itself, which is approximately 70,000 psi., is of significance only in that when materials weaker than this are joined, tension failure will usually occur outside the joint, and in stronger materials, failure occurs in the joint at loads greatly in excess of the strength of the brazing alloy itself; the maximum strength is then determined by the factors enumerated above. These will be discussed in the order listed.

Most metals, when properly fluxed, are readily wetted and bonded by low-temperature silver brazing alloys and the bond strength will be greater than the strength of the brazing alloy itself. In certain cases, particularly in alloys containing aluminum, special fluxes are required to achieve this wetting; and in certain other cases, a brazing alloy containing a small percentage of nickel should be used, viz., for brazing cemented carbides. Generally, it is only in very hard and strong materials that the bond between the brazing alloy and the metal or metals being joined is the determining factor in joint strength.

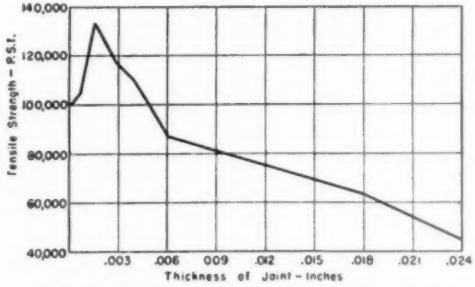

Fig. 1 Effect of joint thickness on tensile strength

Figure 1 is a curve of the effect of joint thickness on strength. The data were obtained from butt joints in stainless steel sheet 0.031 x 0.5 in. having an as-received strength of 160,000 psi.

On soft materials, the thickness of joint is relatively less important. On strong materials it is a major factor.

The curves in Figs. 2 and 3 show how several different thicknesses of joint vary in strength with the strength of material being joined. These data were obtained from 0.505-in. diameter standard tension specimens having a butt joint at the middle of the 2-in. gauge length.

It has not been possible to determine the limiting value of joint strength. Theoretically the maximum strength should have been obtained in high-speed steel since this material did not anneal appreciably at the brazing temperature. However, failure here was at the brazing alloy-steel interface, i.e., the bond. The bond was not strong enough to transmit sufficient stress to break the brazing alloy itself when the brazing alloy was restrained by hardened high-speed steel. In the case of the heat-treated S.A.E. 4140 steel, the bond held and the break occurred in the brazing alloy. The

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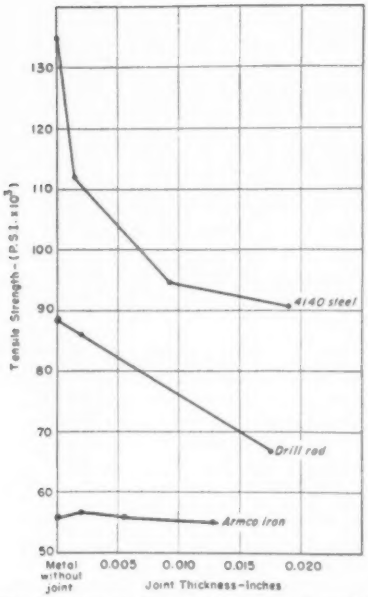

Fig. 2 Effect of joint thickness on the tensile strength of Easy-Flo brazed joints

breaking strength of the joint was about coincident with the yield strength of the steel.

The question of why or how a silver brazing alloy with an ordinary tensile strength of about 70,000 psi. can withstand a stress of 130,000 psi. cannot be answered with certainty. The following theory is suggested: When the brazing alloy is stressed, it tends to elongate. However, elongation requires a collateral reduction in area, and this reduction in area is restrained in the joint by the closely spaced, hard faces of the steel to which the brazing alloy is bonded. The brazing alloy is then under triaxial tension. It has been established that a material under triaxial tension has a higher breaking strength along the principal axis of stress, and a lower elongation, than when pulled in simple tension. When the yield point of the steel is reached, the steel elongates and, collaterally, reduces in cross section. This, then, means a relaxation of the lateral or radial tension stresses in the joint and the brazing alloy may then extend out to failure.

The joints from which these data were obtained were of a quality not usually attained under ordinary circumstances. Each joint face was first "tinned" with the brazing alloy and then the two flux-covered "tinned" faces were wiped together shearwise by which means most of the flux was removed from the joint. In nearly all cases where the alloy is flowed into the joint, or preplaced as a shim, some flux inclusions will be retained and these will reduce the joint strength by some factor related to the ratio of the cross-section area of included flux and the area of the brazing alloy.

The shear strengths of brazed joints (rod and sleeve, lap and torsion) are governed by somewhat similar considerations. The increase in the shear strength that occurs with increased strength of the metals joined is not so great as in the case of tension joints. Nor is a thin joint necessarily the strongest in all cases. When hard, brittle materials are silver brazed, higher shear values may be realized with thicker joints and, conversely, thin joints have given higher values in soft, ductile materials; but in most cases the differences are small.

The curve in Fig. 4 obtained from torsion tests of wiped joints (similar to the tension joints just described) shows the relationship of material strength to shear strength. The curve shows the maximum shear stress in torsion according to the formula $S = 12T/\pi d^3$, where S = stress, T = torque, d = diameter. What collateral stresses exist in addition to the principal shear stress are even more obscure than in the case of tension. The limiting value of shear stress has not been determined. Isolated instances of shear strength as high as 48,000 psi. have been encountered.

The strength that may be realized in a structure will depend also on the mechanical characteristics of that structure. If the end of a rod is brazed to the face of a plate, and the rod is pulled while the plate is held at the edges, the plate will bow and the thinner the plate, the more it will bow. There is then a bending moment between the plate and the rod and the resulting tension stresses arising from this bending moment at the outside edges of the joint are additive to the principal direct tension stresses in the joint. This stress concen-

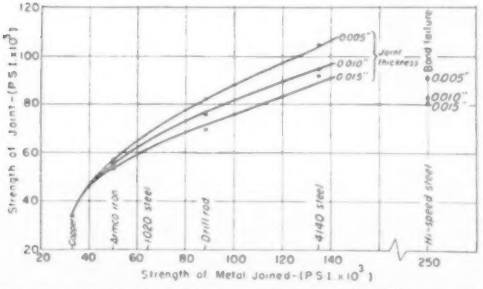

Fig. 3 Relationship of joint tensile strength with strength of metal joined

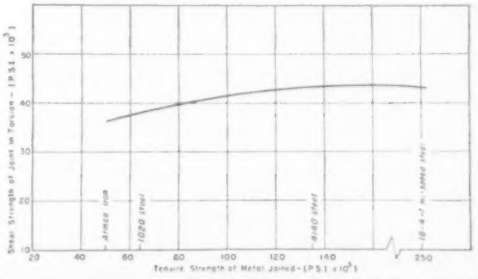

Fig. 4 Relationship of joint shear strength with strength of material joined Easy-Flo brazed joints

tration will start a failure at a lower average stress than the calculated average strength of the joint (assuming uniform stress distribution) and the joint will then fail progressively by tearing.

Similarly in a rod and sleeve joint, where the shear area is such that the calculated strength of the joint is greater than the yield strength of the rod, and the sleeve is stronger than the rod, failure may still occur in the joint instead of the rod. First, because of differences in elastic extension or strain in the two members, the shear stress is not uniformly distributed but is higher where the rod first meets the collar or tube; and second, the tendency of the rod to reduce in diameter as it elongates causes a radial tension stress in the brazing alloy. Again these secondary stresses added to the principal stress will start a failure at a lower *average* stress than the calculated strength of the joint and the joint will then fail progressively by tearing.

An examination of the impact properties follows. The impact strength of a brazed joint measures the ability of a *structure* to absorb impact energy, and the brazed joint may or may not be the controlling element in the structure.

An impact test measures the energy required to break a particular specimen and this energy is the product of two components: (1) the force and (2) the distance through which the force must move to cause failure. Consider the case in which relatively soft metals are butt joined with a relatively strong brazing alloy to make an Izod test specimen. In the impact test the metals joined will elongate appreciably on the outside of the bend before the joint breaks. The elongation in the metal joined is spread over an inch or so of the length of the specimen and may be in the order 25% or $^1/_4$ in. The joint itself which is in the order 0.002 in. thick may also elongate about 25%. The absorbed energy is then derived from the average force times the elongation of the steel (0.25 in.) plus the average force times the elongation of the brazing alloy (0.0005 in.). It will thus be seen that the steel absorbs 99.8% of the energy and the brazing alloy only 0.2% by virtue of its short length (thickness).

Consider now the converse situation where the steel is much stronger than the brazing alloy. In the case of heat-treated S.A.E. 4140 brazed with Easy-Flo, the brazing alloy will fail at about 111,000 psi., or at about the yield point of the steel. In this case the brazing alloy is not strong enough to stress the alloy steel beyond its yield point. The total elongation will only be about 0.001 in., all of it in the brazing alloy, and the total energy absorption will be small; much less than the impact strength obtained in the previous case with the same brazing alloy.

Thus, if the joint is strong enough to cause the structure to deform, high impact strength will be obtained. However, if the structure is such that it will not deform before the breaking strength of the joint is reached, then low impact strength will result because the elongation that can occur in a butt joint is only a few thousandths of an inch at best, even with an exceptionally ductile brazing alloy having an elongation greater than 50%.

A summary of impact test data is tabulated below:

Unnotched Izod Impact Tests (Averages)

	S.A.E. 4141 steel, ft.-lb.	Armco iron, ft.-lb.
Brazed with ductile alloy (Easy-Flo*)	1.7	39.9
Brazed with semibrittle alloy	1.6	12.1
Brazed with very brittle alloy	1.6	1.8

* Proprietary alloy (50 Ag, 15.5 Cu, 16.5 Zn and 18% Cd).

The impact test specimens were standard Izod specimens machined from round bars and brazed with the same wiping technique that was described in the case of the tension and torsion specimens.

In design, the mechanical relationship of the joint to the rest of the structure, the joint size, location and stress as related to the loads applied to the structure, and the ability of the structure to "give" or yield under impact before the breaking strength of the brazed joint is exceeded are all important considerations. When strong materials are to be joined, it is advisable to provide some link in the structure that will yield and absorb impact energy.

In Fig. 5 (*a*) shows the Izod impact test specimen on which the test results tabulated above were obtained. If (*a*) is assumed to be of high-strength steel and if the steel is machined off to produce the specimen shown at (*b*), the impact strength will be increased because in (*b*) a structure is produced that will deform in the steel before the joint breaks. The scarf joint (*c*) will also have a higher impact strength because the joint intersects the surface at a point removed from the location of highest bending moment (the center).

With soft materials such as copper or low-carbon

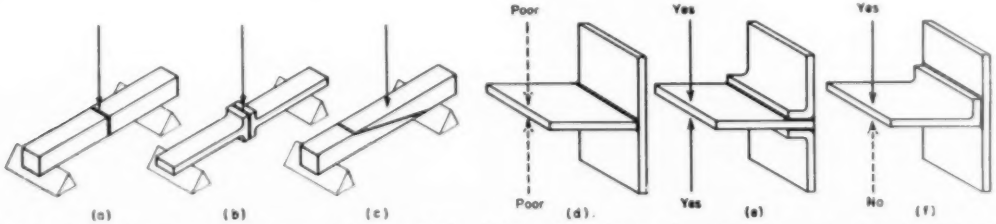

Fig. 5 Types of impact test specimens, (a), (b) and (c): joint designs (good and poor) for impact loading, (d), (e) and (f)

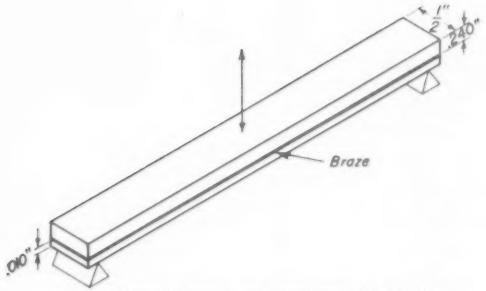

Fig. 6 Brazed flexure test specimen (fatigue)

steel, *T* joints such as (*d*) can be used, but designs (*e*) and (*f*) are obviously preferable, and with strong materials subject to impact loading (*d*) should be avoided.

Fatigue is governed by many of the same considerations from the design standpoint. The fatigue strength of a material is generally proportional to the tensile strength and where soft materials such as low-carbon steel or copper are joined, the tension-compression fatigue strength of the brazed joint is of the same order of magnitude as the material joined up to about 27,000 psi. In stronger materials the brazing alloy layer is relatively softer, and the fatigue strength of the stronger material cannot be realized unless the design is such that the fatiguing stress in the brazing layer is relatively low. In the absence of better information, stress should preferably not exceed 27,000 psi. in a butt tension joint.

On the other hand, a brazed, laminated, flexure specimen of heat-treated alloy steel such as that shown in Fig. 6 may have an endurance limit approaching that of a solid bar of the same steel, same dimensions and heat treatment, i.e., in the order of 75,000 psi. maximum fiber stress in the steel when the thickness of the brazing layer is carefully controlled and inclusions are held to a minimum.*

* Army Air Forces, Air Materiel Command—Technical Report 5602 (not Classified or restricted).

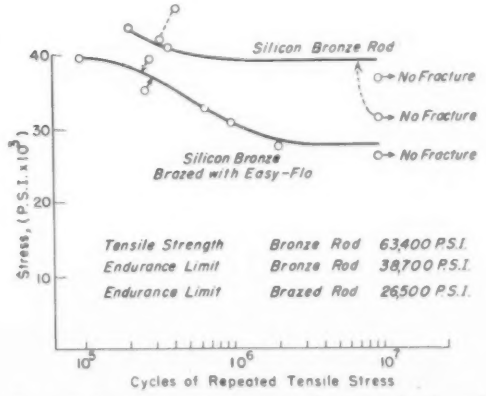

Fig. 7 S-N curve for silicon bronze—brazed and unbrazed

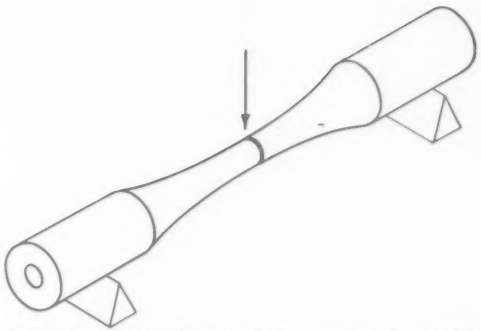

Fig. 8 Standard R. R. Moore fatigue-test specimen with brazed joint in center

Figure 7 is an *S-N* curve for a Moore rotating beam test of silicon bronze, butt brazed at the center with Easy-Flo. Unfortunately, the specimen (Fig. 8) that must be used for a fatigue test is again a poor (just about the worst) design for practical application. In this case, discontinuities in the brazing layer which are exposed by machining can intersect the surface and form notches or stress raisers which will lower the fatigue limit. Better practice would place the joint in a region of lower stress rather than at the most highly stressed point; further, the brazing layer should not intersect a very highly stressed surface if it is to be subjected to repeated loading and unloading or to stress reversals, i.e., fatigue. The test, Fig. 6, was only run for 10 million cycles. A more critical evaluation of fatigue properties should be run for 100 million or more.

The specimens shown in Fig. 9 (*a* or *b*) would be better rotating beams from the practical standpoint, but could not be used to determine the tension-compression fatigue limit of a butt joint. Note the use of tapered collars to avoid stress concentrations that might result if a more abrupt change of section were used.

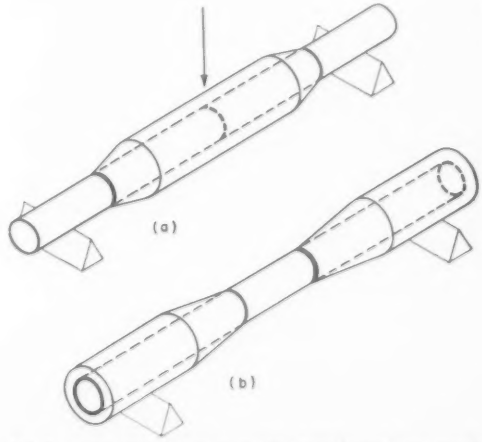

Fig. 9 Practical types of rotating beam brazed test specimens

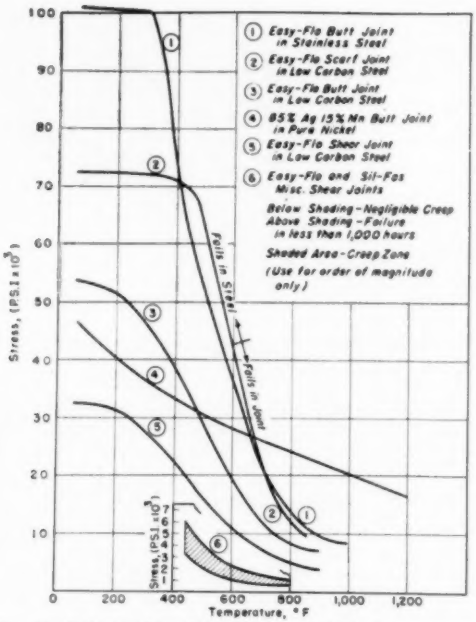
1 Easy-Flo Butt Joint in Stainless Steel
2 Easy-Flo Scarf Joint in Low Carbon Steel
3 Easy-Flo Butt Joint in Low Carbon Steel
4 85% Ag 15% Mn Butt Joint in Pure Nickel
5 Easy-Flo Shear Joint in Low Carbon Steel
6 Easy-Flo and Sil-Fos Misc. Shear Joints
Below Shading - Negligible Creep
Above Shading - Failure in less than 1,000 hours
Shaded Area - Creep Zone
(Use for order of magnitude only)
Fails in Steel
Fails in Joint
Stress, (PS.I. x 10³)
Temperature, °F

Fig. 10 Relationship of joint strength with temperature

Silver brazing alloys are, for the most part, low melting point alloys as compared with the steels, and as metals weaken rapidly as they approach their melting points, silver brazed joints weaken at lower temperatures than do the metals that may be joined. Figure 10 shows the effect of temperature on strength.

Generally, the short-time tensile strength of Easy-Flo joints is about halved when the temperature is increased from 70 to 500° F. and this applies to both butt and shear joints, and to joints in soft or hard steels. However, where the joint is so constituted that the failure ordinarily occurs outside the joint (Curve 2, Fig. 10), better than 50% strength may be realized at 500° F. With higher melting brazing alloys (Curve 4, Fig. 10), better high-temperature properties may be obtained.

Silver brazing alloys, like all metals, are subject to creep at elevated temperature and to failure at high temperature under long-time loading at stresses lower than the short-time tensile strength (see Curve 6, Fig. 10). The shaded area includes a number of points from creep and stress rupture tests on Easy-Flo and Sil-Fos shear joints made in several different laboratories. The curve should not be used for design purposes, but is shown only to bracket the magnitude of the time-temperature-load relationships as compared with short-time high-temperature shear strengths (Curve 5, Fig. 10).

In summary, it is apparent that no broad generalizations can be made, nor any general formula applied, to define or establish joint strengths for all cases. Suffice it to say that when metallurgical and mechanical considerations are favorable, joint strengths up to 130,000 psi. in tension and 48,000 psi. in shear can be obtained. For other than these ideal conditions, the joints may be weaker depending on the factors enumerated at the beginning of this paper, viz:

1. The degree to which the materials being joined are wet by and bonded to the brazing alloy (deficient only in special cases).
2. The thickness of the joint.
3. The strength of material being joined.
4. Flux inclusions.
5. Mechanical characteristics of the structure which cause uneven stress distribution.

Lest this list of detractors from strength imply a greater limitation on practical applications than the facts justify, some examples of the abuse which joints will withstand should be recited.

Copper and brass rods, butt brazed, may be drawn down to fine wire. Plates having a cladding of other metal brazed to the face may be rolled into thin sheets. *T* or *L* joints in plates or sheets of ductile material can be hammered flat without breaking. Sheet products having brazed seams have been formed, drawn, beaded, etc. Where joint failures in ductile materials occur because of stress concentration, the failure usually involves the tearing out of pieces of the metal joined.

A generalization that can be made is that joint strength is not *usually* a limitation in the design of structures to be joined by brazing. Where a quantitative measure of strength is necessary, an actual physical test of the *structure* is indicated.

ACKNOWLEDGMENT

Acknowledgment is made to W. D. Warren, Metallurgist, Handy & Harman, who supervised many of the tests reported here. The earlier work of R. H. Leach, Vice-President, and of C. H. Chatfield, Senior Metallurgist, Handy & Harman, has also been used extensively.

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(*Continued from page 461*)

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Welding Shop Fabricates Two Useful "Helpers" for Farm

WHEN an up-and-coming welding shop and a wide-awake farmer get together, the shop makes money and the farmer gets himself some well-made equipment at low cost.

That is what happened when one farmer needed a strong, light-weight rubber-tired farm wagon. The materials used for the chassis were simple. A couple of old automobile front ends and a few lengths of salvaged pipe, plus arc and gas welding, turned the trick.

The spindles on the rear axle were welded in position to keep the back wheels from turning. A length of 3-in. pipe was welded to the center of the axle and the entire assembly made rigid by welding the point of the wishbone to the pipe.

The spindles of the front wheels were allowed free play and the tie rod left in position. An ingenious arrangement swings the wheels in the direction of the pull on the tongue or tractor hitch. A piece of $2^1/_2$-in. pipe was welded to the axle and the wishbone point was welded to the pipe in the same manner as the rear end. The $2^1/_2$-in. pipe telescopes into the 3-in. pipe, forming the pole of the wagon and joining the front and rear ends. A $^3/_4$-in. hole was drilled through the 3-in. pipe

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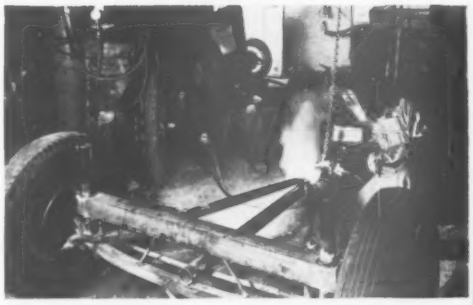
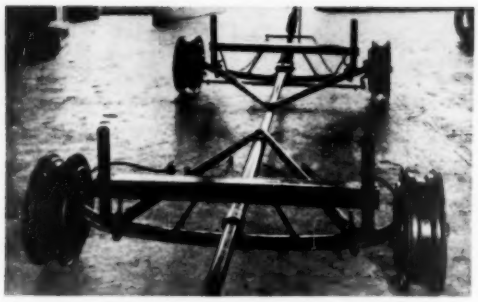


Welding the frame for the farm wagon, using two front axles and pipes

Hay buck welded from an old Buick and International truck more than pulls its own weight on the farm



The chassis before leaving the shop, ready for tires and body

At the farm, the wheels indicate that the wagon has been put to good use

about 6 in. from the front end. Similar holes were drilled at regular intervals through the smaller pipe. The wheelbase is adjusted by sliding the smaller pipe forward or backward inside the larger to the desired position and dropping a $^3/_4$-in. bolt through the holes in both pipes.

The hay buck is another interesting example of a valuable new labor-saving implement which was built with the aid of welding. The front end and power plant were taken from a 1929 Buick. The rear end and transmission were taken from an old International truck because the two-speed transmission permitted construction of a pulley drive from the drive shaft to operate the drum which raises the rake allowing this operation to be carried out while the buck is standing still. The two sections from two different vehicles were welded together into a single rigid unit. Welding was also employed in the construction of the rake itself and in building the mounting for the hoist drum.

Flame-Cutting Stainless Steel by New Method

FABRICATION of an 18-8 stainless steel Diesel water tank required the cutting of two 10- x 18-in. holes in the 10-gage material on each side of the tank. It was planned to weld a recessed section for water and air connections into these holes.

The Oxweld powder-cutting process proved to be a quick and efficient method to accurately cut holes in the curved side of the stainless steel tank. In this process an iron-rich powder is automatically added to the cutting-oxygen stream. This releases large quantities of heat and creates superheated particles of iron oxide. The burning of the iron powder permits the cutting oxygen to oxidize the base metal. Quality of the cut compares favorably with that obtained in plain oxy-acetylene cutting of carbon steels.

The blowpipe used was the Oxweld AC-4 powder-cutting blowpipe. Cutting oxygen was at a pressure of 75 lb. and acetylene at 10 psi. Compressed air at 18 lb. pressure forced the powder into the stream of oxygen. The rate of cutting was 12 in. per minute.

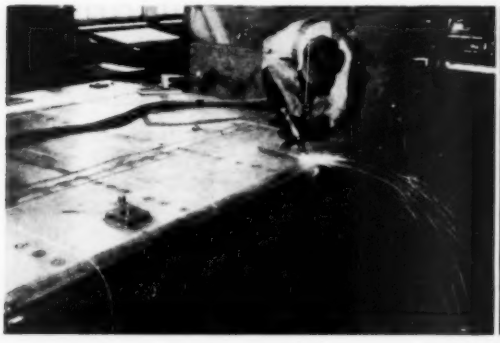
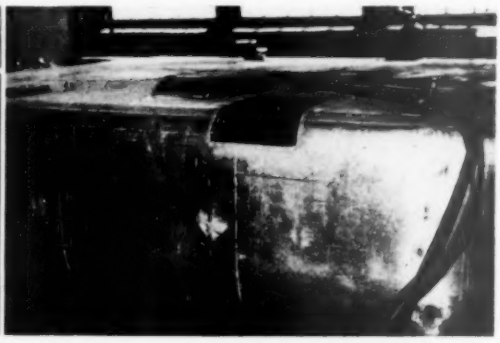


Fig. 1 Operator is using a powder cutting blowpipe to cut 10-gage 18-8 stainless steel at 12 in. per minute



Photos Courtesy The Linde Air Products Co.

Fig. 2 Finished powder-cut hole has smooth edges that need only a minimum of finishing

How to Repair Grate Bars

Clean the broken edges if you want to make a strong repair

by F. C. Geibig

A JAMMED clinker—an extra strong yank on the shaker—snap goes a grate bar. New grate bars are not always available and Mr. Jones on Elm Street or Mr. Smith on Maple Street tries to get along with a makeshift furnace for a week or two. Of course, the grate bar only breaks during winter when the furnace is needed. This is where the welding shop comes in, because most grate bars can be welded.

You will probably find that the metal in the grate bar does not melt readily. It will seem to behave almost like a section of firebrick. However, you can make a satisfactory repair by following these instructions. When you repair broken grate bars or other stove and furnace parts remember one thing—careful preparation is half the job. Bevel the broken edges to form a double vee, each with a 90° angle. Where the bevels meet, the touching surfaces should be about $^1/_8$ in. in width. Use a grinding wheel for the beveling. Then clean the casting along the beveled edges and for at least one inch back. In this case, cleaning means the removal of all scale and rust down to the base metal. Careless cleaning will probably produce porous spots and blowholes in the weld because some impurities cannot be removed even when you use the best flux.

When you have properly prepared the parts, match the broken pieces together and block them in position. You can do this with firebrick, welding carbon paste or plate, or by adapting one of the work-holding devices in the shop. Use a welding head or tip one size larger than the one recommended for steel of the same thickness. Then play the flames along the sides of the vee until the entire joint has been thoroughly preheated to a dull red. Usually, you do not have to preheat the entire casting because each end is free to expand when the casting is heated. During this preheating operation sprinkle a generous amount of flux in the weld area. (Use $^1/_4$ in. cast-iron rod and flux.)

Hold the flame 1 to $1^1/_2$ in. from the work to get a good soaking heat in the weld. It is almost impossible to melt the metal when the grate bar has been used for even a short length of time. You are ready to weld when the surface of the metal in the vee begins to appear shiny or oily. Add molten metal from the welding rod immediately. At first you will get what amounts to a tinning action because the original metal has not melted. When the vee and $^1/_2$ in. of the surface on each side of the break have been "tinned" in this way, you can proceed as though you were doing any cast iron welding job. Start at one end of the vee and remelt the "tinned" metal only. Then add molten welding rod metal and form a molten puddle. Use flux generously and continue to add welding rod until the weld metal is about $^1/_8$ in. higher than the surface of the grate bar. The weld metal should extend for about $^1/_2$ in. back from the edges of the vee.

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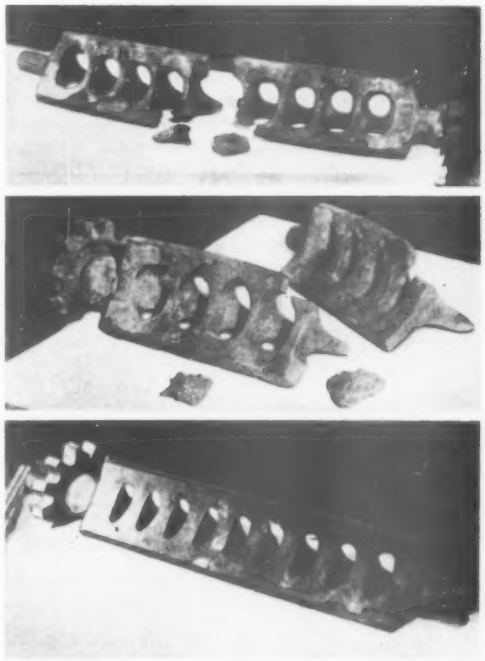

Fig. 1 (Top) This is the grate bar as it was brought into the shop. (Center) The edges to be joined were cleaned and ground to a double vee. (Bottom) The welded grate bar is ready to be put back in operation

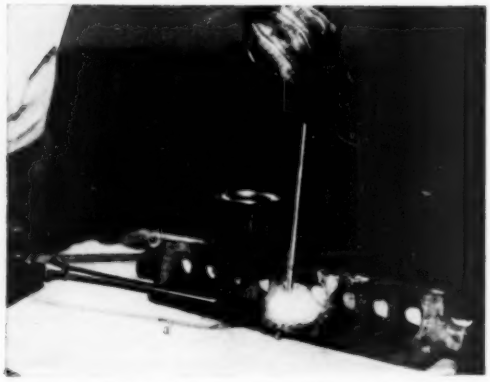

Fig. 2 Apply flux liberally. Impurities can be skimmed from the surface of the puddle with the end of the welding rod

USE FLUX GENEROUSLY

Dip the hot end of the rod into the flux can and then insert it in the molten puddle often during the welding operation. This will help to break up and float out the heavy oxides which are usually present in stove and furnace castings. If gas bubbles or white spots appear in the puddle or at the edges, add flux and direct the flame around the speck until the impurities rise to the top. Then skim them from the weld with the end of your welding rod. If any impurities stick to the hot rod remove them by tapping the rod on the table. Remove all dirt and impurities carefully because any left in the weld will make the joint weak.

When you add rod to the molten puddle, always be sure to submerge the end of the rod in the puddle. Don't hold it above the weld and let it melt drop by drop into the puddle. When one side has been completed, turn the casting over and weld the opposite side in the same manner. Support the bar properly to prevent sag in the portion that has already been welded. Then lay the grate bar in a place where it will cool slowly to room temperature. When it is completely cool you can clean the weld with a wire brush and grind it smooth. Leave as much weld metal as possible to act as reinforcement.

Designing for Welding—Part V

by Wallace A. Stanley

THE simplest form of projection is shown in Fig. 1 and is used in joining stampings of flat or irregular shape and also for joining stampings to machined parts. The size and shape of the projection should vary with the thickness of the material being welded as noted in Fig. 2. On thinner stock, a shallow "radius" projection (called a "button" projection) may be used, increasing to a large, flat topped dome on heavier materials.

There are several factors to be considered in the selection of shape and size of projections for projection welding. The particular problem should be studied with the following considerations in mind:

1. The projections must be strong enough to support the initial pressure before the welding heat is applied. If the area of the projection is too great it will collapse before the weld is started (Fig. 3). This results in increased contact area with the possibility of a weak or poorly formed weld (Fig. 3*a*).

2. The mass of the projection should be such that it will not collapse before it raises the temperature of the contacted sheet to the fusion point for welding. On the other hand if the projection is made too large, complete fusion may not take place and the parts will not be brought into intimate contact at the end of the heating cycle. Too large a projection also results in a tendency

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Fig. 1

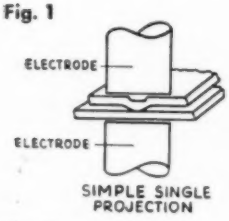


Fig. 2

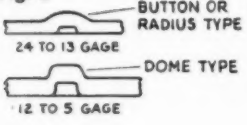


Fig. 3

Fig. 3a

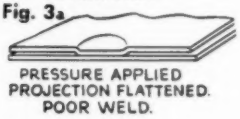


Fig. 4

Fig. 5

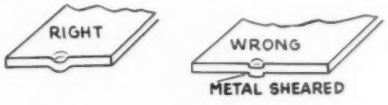


Fig. 6

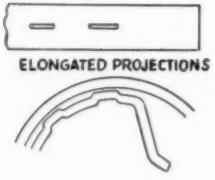
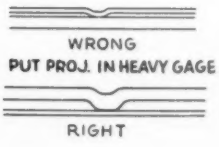


Fig. 7



to produce spitting or splashing at the faying surfaces (Fig. 4) due to the excess heat necessary to produce this weld. This also may produce a poorly formed weld.

3. Care must be taken to avoid any shearing action in the metal when the projection is formed, since this weakens the structure of the metal surrounding the weld (Fig. 5). Proper design values are given in the standards of the A.W.S. A rough approximation for the diameter is twice stock thickness plus 0.031 in. Height of the projection should be roughly 1/4 the diameter.

4. Inasmuch as fusion first starts at the center of the projection (where the greatest heat is concentrated) and works out to the edge, the preferred shape of a projection is round. It can however, be made in any desired shape. On curved surfaces the projections should be elongated in form, the width, however, being the same as the diameter in a button type projection (Fig. 6). This method takes care of any discrepancy in the shape of the curved parts and provides good contact without reducing the current density.

5. Whenever possible the projection should be formed in the heavier part since this gives the concentrated area of the heavier part a better chance to reach welding temperature simultaneously with the thinner part before the collapse of the projection (Fig. 7). The projection concentrates the current flow, and therefore the heat of the part, into a small area thus permitting a *heavy* part to reach fusion temperature in the localized area. If the projection were in the thinner part instead, the heavier part would dissipate the heat from the localized area opposite the projection too fast to reach fusion temperature at the same time the projection area of the thinner sheet reaches fusion temperature. Result: the collapse of the projection in the thinner piece *without* fusion with the thicker piece. Projections *can* be placed in the thinner sheet if necessary, however, although greater care must be exercised in the design of the projection as to size and shape, while dies and electrodes should be used in special combinations. If the latter practice is to be followed, it is wise to test experimentally formed projections as a double check on the soundness of the welds to be anticipated in production. (*Continued in next issue*)

Mechanized Flame-Cutting Lengths of Pipe

by A. H. Wilson

SHOPS which may, from time to time, be required to cut quantities of short lengths of pipe, but not sufficiently to warrant investment in sawing equipment can obtain good and efficient results with a power-driven flame cutting set up along the lines illustrated in Fig. 1.

A variable speed power source, such as a Radiagraph, is suitably geared to a length of pipe, fitted with stub shafts which are supported in bearings. This provides a driven roller. A similar length of pipe, mounted in bearings, parallel to the driven roller, provides an idling roller. The torch is mounted at the end of the rollers away from the Radiagraph, with standard adjustments for height and lateral position, so it can be set to the

A. H. Wilson is with the St. Louis District of the Air Reduction Sales Co.

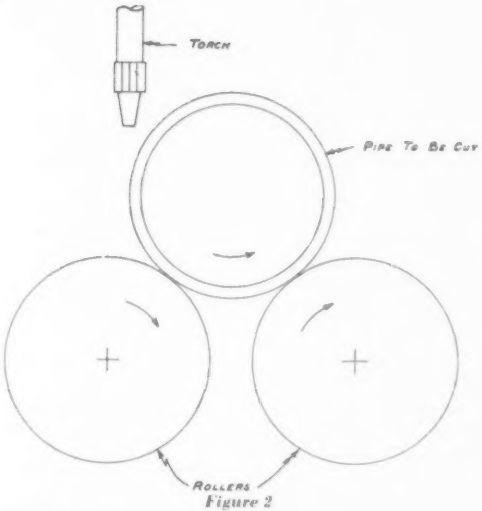


Figure 2

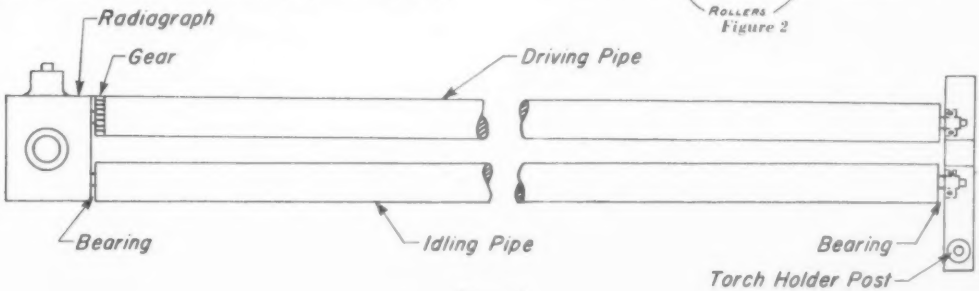


Figure 1

cutting position diagrammed in Fig. 2, whatever the diameter of the pipe to be cut may be.

An adjustable stop can be arranged for repetitive cutting of duplicate lengths, and when the rig is not in use, the Radiagraph can be used for its regular cutting work. All that is required to attach it to or detach it from the pipe-cutting rolls is the exchange of one drive-wheel for a gear.

Heating, Forming and Bending by the Oxyacetylene Process

Extracts from paper presented before The American Welding Society, Chicago Section Meeting, January 21, 1949

by William A. Thiel

THE fact that metals expand or contract with changes of temperature is well known to every one, and is easily understood. It is also known that these forces extend in all directions simultaneously. If the forces of expansion are resisted by other parts of the member or structure or by cold metal adjacent to the heated area, expansion is constrained and the heated metal will be upset if the yield point at that particular temperature has been exceeded. The upset metal, when cooled is shorter than it previously was and exerts a pulling force on the adjacent metals and can be used to cause a straightening effect. Take for instance a bar which has been bent into a slight bow. By heating on the convex side the forces above described are brought into play, the convex side shortened when cooled, and straightening forces effected, by pulling the other side up into a straight line. Similarly a bulge may be flattened by heating the top of the buckle or bulge, and the same forces effect a straightening operation. The application of these principles to structural steel result in application to a number of structural members, plain or fabricated and a few practical examples will be given.

1. Straightening materials, such as plates, structural shapes and particularly welded materials. It has become commonplace to straighten with heat, at a great saving in time. These have to be handled as individual cases but the basic principles employed are the same as above.

2. Straightening flanges particularly on pieces such as welded girders. Due to welding, the flanges tend to bend in. By application of heat on the outside of the flange and in line with the web, forces are exerted that will pull the flange into a straight position.

3. Treatment of buckles. By heating the bulged part of the buckle in one or more places, the buckle can be removed and the plate successfully straightened.

4. Cambering beams. It often is necessary to camber beams. Rather than move them to a gagging press, the use of the oxyacetylene torch permits the cambering operations to be done at the skid, applying heat on the side that is to have the camber. Heat is applied at several locations, spaced according to the size and length of the beam and the amount of camber desired. Sometimes water is used to assist in cooling but more often it is not found necessary.

5. Structural fabrication. It sometimes becomes desirable to bend various structural pieces in the course of fabrication. If only one or two pieces are required and it is not economical to set up various machines such as presses or bulldozers, by heating locally on the bend line and by application of mechanical force, it becomes economically feasible to perform this operation, some times at the fitting skid. The ease of heating localized areas and the speed of the operation are factors in this class of work. The heating torch is often used as a valuable adjunct to the fitting skid especially in fitting complicated bent work and irregular shapes that are hard to fit.

6. Flame softening. In the use of structural alloy steels such as silicon or nickel steels, it is often desirable or necessary to flame soften the flame-cut edges of the material. This is usually done for two purposes: first, to relieve strains that might exist should the flame-cut edge be too suddenly cooled, and second, to soften the edge so that it may satisfactorily be machined. Plates often must be edge-planed and beam or column sections must often be milled for bearing. To pass a heating torch over the flame-cut edge flame softens it so that satisfactory machining can be done, and in the case of the flame-cut edge left unmachined, the rate of cooling can be controlled by means of a heating torch, eliminating to a great degree the strains resulting from rapid cooling. The heating torches may be manually operated or a heating torch may be mounted on the shape-cutting machine so arranged as to follow immediately behind the cutting blowpipe.

7. Preheating and controlled cooling. The heating blowpipe is very valuable to preheat for welding, and also to assist in the controlled cooling of weldments where the operation is of a local character and does not

William A. Thiel is Superintendent of Construction and Maintenance, American Bridge Co., Gary Plant, U. S. Steel Corp. Subsidiary.

warrant placing the weldment in a furnace for heating or cooling.

For repair work on steel or iron castings especially where the repair is made by bronze welding, the use of an additional heating blowpipe is often desirable in addition to the welding blowpipe, and is of great benefit in all phases of the welding operations such as preheating, maintaining heat and equalizing the heat prior to controlled cooling. Extensive repairs to gears, machine frames and other machine parts have been successfully made.

TYPE OF EQUIPMENT USED

The equipment found to be most useful is a welding blowpipe with a multiflame tip. The capacity required will vary with the job. For the heaviest and most rapid heating, a blowpipe having a capacity up to 250 cu. ft. per hour with a round tip having about 21 flames, has been found very satisfactory. This has a very rapid heating capacity and is found to be a dependable portable tool.

For fuel gas, various fuels of the propane type may be used, but it has been found desirable to use acetylene because it lends itself easily to being generated on the premises and piped throughout the working areas of the shop and yard. Piped oxygen and acetylene are found to be desirable for several reasons:

1. It is cheaper to purchase oxygen in large lots and pipe it to locations where needed than to use cylinder oxygen. Likewise it is cheaper for quantity consumption to purchase carbide and generate acetylene than to purchase it in individual cylinders.
2. The use of piped gases entirely eliminates cylinder handling which even under ideal conditions is quite costly.
3. The use of piped gas eliminates waiting time by burners, welders and heaters while cylinders are changed, and it is necessary to move only the regulators, hose and blowpipe when moving from one location to another.

A Handy Clamp for Lining Up Pipe

by L. W. Young

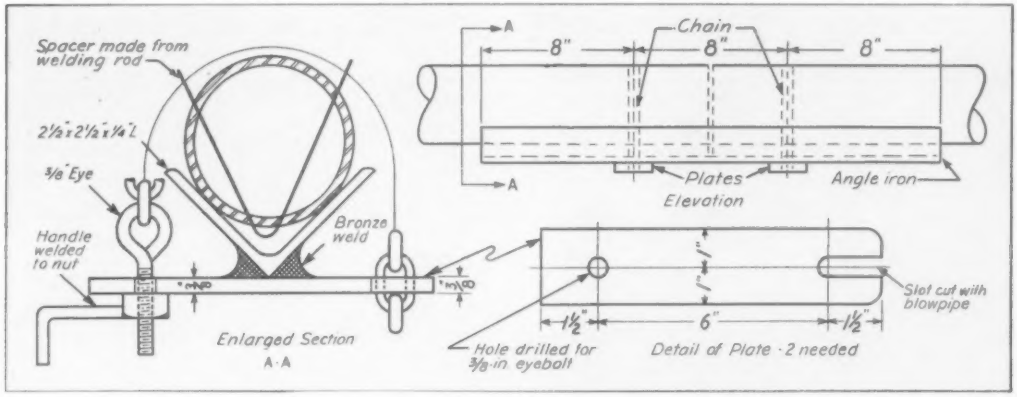
YOU can do a better welding job on pipe when you get the proper space between the ends, and hold that spacing by proper clamping. The accompanying sketch shows how to make a simple clamp from material you probably have in the shop now.

To set up the clamp for welding, place the two pipe sections in the angle iron trough. A spacer, made of welding rod, is the simplest method to obtain the proper spacing between the pipe ends. To make the spacer, use your blowpipe to heat a piece of welding rod of the desired diameter. Then bend it to a V-shape. Place the spacer rod between the pipe ends, as shown in Fig. 1.

Then butt the pipe sections against the rod and fasten the clamp. To make the clamp secure, draw the chains over the pipe and slip a link into the slot. One of the links must bear on the underside of the base plate, as shown in the sketch. Then turn up the nut until the chains are tight. Pull out the spacer rod and make several tack welds. Loosen the clamp and make the finished weld.

This clamp can be used on pipe up to 3 in. in diameter. For larger pipe, increase the length of the angle iron, the base plate and the chains.

L. W. Young is with The Linde Air Products Co., Newark, N. J.



This sketch shows the construction details of a simple clamp for lining up pipe

Resistance Welding at Work

MOTOR HOUSINGS

HERE an electric motor housing composed of 7 parts is loaded on a 10-station indexing table and welded at the rate of 2000 units per hour. The table is ratchet actuated and is synchronized with the welder. Shaped mandrels mounted on the table serve as loading fixtures for parts other than those being welded. As indicated in the diagram, most of the feeding is by hopper or magazine—with two operators loading where automatic feeding is not practical.

Parts reach the final stage of loading at station No. 8, and station No. 9 completes an unusual projection weld. Slinger shield loaded at station No. 1 and dust cap at No. 8 are preformed with 6 projections each. These two units are simultaneously welded to the shell loaded at station No. 7.

The thicknesses welded are 0.017-, 0.023- and 0.029-in. cold-rolled steel. The completed unit is automatically ejected at station No. 10 into a receiving bin.

The same welder is used to weld a similar, but different sized motor housing assembly. A different index table is used for this and additional hopper feeds are brought into use at stations No. 2 and No. 4.

Data and photos courtesy of Sciaky Bros., Inc., Chicago, Ill.

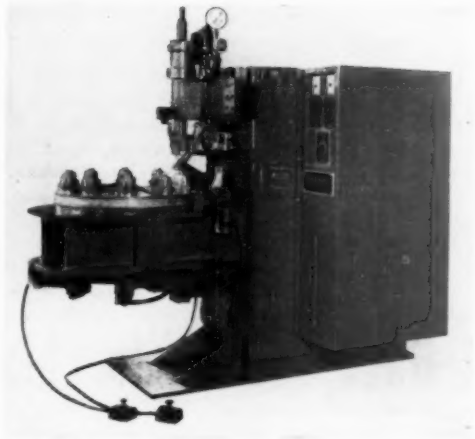


Fig. 2 Sciaky machine for welding motor housings

The Sciaky welder used for this job makes the three-thickness-weld on a power rating of only 100 kva.! This is because it is equipped with "Three-Phase" control—a feature which cuts current required 75%, draws a balanced load at 85% or better power factor.

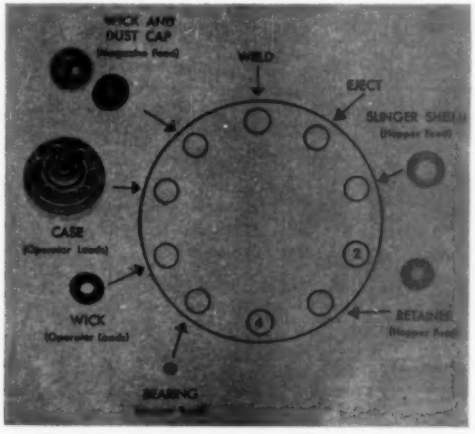


Fig. 1 The above plan-view illustrates how the various component parts of the motor housing are fed, welded and ejected at the various stations. Stations 2 and 4 are used when welding a different size housing

Stud Welding Cuts Plumbing Costs

THE installation of bathroom and kitchen plumbing fixtures in the more than 2200 dwelling units included in the New York Housing Authority's Gowanus and Astoria housing projects has been greatly simplified by the use of stud-welded anchor plates.

The anchor plates are being produced by the J. J. Gribbins Co., Long Island City, to specifications set by James W. Ellis, engineer for Lipsky and Rosenthal of Brooklyn, who have the plumbing and heating contracts for these projects. The J. J. Gribbins Co. also has contracts to provide similar anchor plates for the Gov. Alfred E. Smith and Woodside projects involving 2300 dwelling units.

Simple loading fixtures and templates used in the production of the anchor plates on which female studs are end welded with the lightweight Nelson automatic stud-welding gun have enabled operators to average 30 units per hour. Each bathroom unit has seven studs, four for suspending the toilet bowl and three for the wash basin. Those which support kitchen sink and tray have five studs.

The cost of installing fixtures has been materially reduced by the elimination of through bolts, which make it necessary to run nuts all the way down to the plate before metal lath and plastering is installed. The stud-welded anchor plate is secured to the wall studs with U-bolts in the usual fashion, after which the wall can be entirely finished, since the studs are sufficient to extend through the lath and plaster.

Fig. 1 Female threaded studs end welded to anchor plates with the Nelson stud-welding gun by the J. J. Gribbins Co., simplify the installation of bathroom and kitchen plumbing fixtures in more than 5000 family units at three New York housing projects. This view shows a typical bathroom anchor plate, which is secured to the wall studs with U-bolts. The four female studs in the foreground are for suspending the toilet tank, and three in the background will support the wash basin

Fig. 2 This simple loading fixture facilitates the production of anchor plates used for the installation of plumbing fixtures in three large New York housing projects. One operator can load while another is stud welding; thereby doubling the productivity of the Nelson stud-welding gun

the AMERICAN WELDING SOCIETY

activities • related events

Meeting of Executive Committee of the American Welding Society

A meeting of the Executive Committee was held in Room 1101, Engineering Societies Bldg., New York City, on Mar. 7, 1949, with the following in attendance:

Members: O. B. J. Fraser, H. W. Pierce, R. S. Donald and T. B. Jefferson.

Board Members: D. Arnott and H. O. Hill.

By Invitation: E. Holloway, Attorney; R. D. Thomas, *Chairman*, Permanent Fund Committee and A.W.S. delegate on I.I.W.

Staff Members: J. G. Magrath, M. M. Kelly, W. Spraragen, F. J. Mooney and S. A. Greenberg.

Confirmation of Appointments

On motion, duly seconded, the following changes in standing committee personnel were confirmed:

Program Committee—Replacement of T. C. Fetherston by Homer Morrison, both of The Linde Air Products Co.

Convention Committee—Appointment of M. S. Shane and R. J. Kriz as Chairman and Vice-Chairman, respectively, of the 1949 Convention Committee.

International Institute of Welding

Discussion on matter covered in communication, dated Mar. 7, 1949, to the Executive Committee, Board of Directors, from the Executive Secretary, which was appended to the agenda of this meeting, brought forth the following expressions of opinion:

Since the I.I.W. has been in existence less than a year, it is too soon to determine the value of U.S. participation in this international movement and it is therefore advisable to retain membership for a second year;

there is little possibility, from the standpoint of consumption of time and expense, of having suitable representation at International Institute meetings held abroad;

it does not appear now that there is much more to be gained through membership affiliation than can be obtained from our present procedure of exchange of welding literature with the welding institutions of foreign countries;

for the sake of good will, in so far as manufacturers of welded products and welding equipment are concerned, it is desirable that an indication of willingness to cooperate be demonstrated to foreign interests. Toward that end, it is believed the manufacturers of welded products and welding equipment might be willing to contribute to A.W.S. to such extent that it in turn could support I.I.W. membership affiliation;

in view of skepticism of beneficial results to be derived from continuing membership affiliation, it is believed advisable, in transmitting dues payment for the past year and in apprising of intention of continuing membership for a second year, to acquaint the officers of I.I.W. with the fact that future U. S. representation in I.I.W. will depend largely upon the two years' accomplishments and upon future assessment, both monetary and in services.

Discussion resolved itself into the following motions:

(*a*) that payment be made for U. S. representation in I.I.W. for the calendar year 1948;

(*b*) that U. S. representation, sponsored by A.W.S. and W.R.C., be continued for a second year, at a total cost not to exceed £175, and that in transmitting check to cover the first annual dues payment, the officers of I.I.W. be informed there is some measure of skepticism as to the benefits that might be derived from U. S. representation in this international movement and U. S. representation in the future will depend largely upon results attained and membership assessment in money and services;

(*c*) that in view of possible special interest on the part of a number of the manufacturers of welded products and of welding equipment in having representation in I.I.W., it is in order to solicit voluntary subscriptions from them toward underwriting the expense of such representation.

It was reported by the Executive Secretary that Dr. A. B. Kinzel, the designated Vice-President and one of the U. S. delegates in I.I.W., has advised of his inability to attend the next meeting of I.I.W., scheduled to take place this spring in Holland. Howard Beers, of the same company, will attend the coming Congress and is agreeable to representing the SOCIETY at this Congress, if such move is acceptable to the SOCIETY.

Upon motion, duly seconded, it was voted to accept Dr. Kinzel's suggestion to have Howard Beers, of the Union Carbide & Carbon Research Labs., substitute for Dr. Kinzel at the Congress, to be held this spring in Holland.

Appointment of Assistant Secretary and Assistant Treasurer, A.W.S.

Communication, dated Mar. 7, 1949, to the Executive Committee, Board of Directors, from the Executive Secretary was duly considered, after which it was voted to recommend to the Board of Directors for approval appointment of F. J. Mooney to the offices of Assistant Secretary and Assistant Treasurer, effective May 1, 1949.

Retirement of Secretary of the Society

During the discussion of this matter, the Secretary was excused and Mr. Jefferson, serving as Secretary pro tem, recorded the passing of the following motions:

Resolved that recommendation be made to the Board of Directors of the SOCIETY:

that provision be made in the A.W.S. by-laws for position of Secretary Emeritus by adding a new section, to be known as Section 12, Article VIII, reading as follows:

"Article VIII, Section 12. Secretary Emeritus. The Board of Directors may from time to time, in its discretion, appoint any past Secretary of the Society 'Secretary Emeritus,' for such term and with compensation and duties as the Board may designate";

that the office of "Executive Secretary" be abolished and the duties of that office be combined with the duties of "Secretary" to take effect at the end of the current fiscal year;

that M. M. Kelly be elected to the office of "Secretary Emeritus," effective as of Oct. 1, 1949;

that draft of contract between A.W.S. and Secretary Kelly, prepared by the SOCIETY's attorney, with such modifications as were approved by the Executive Committee at this meeting, be recommended for adoption by the Board of Directors;

that Secretary Kelly be requested to attend the May 1949 Board of Directors' meeting and that leave-of-absence, at full salary, be granted her from June 1st to and including Sept. 30, 1949.

Restoration of Sustaining Member Benefits

The Executive Committee voted approval of recommendation of the Finance Committee, namely, that action of the Board of Directors at its meeting in Buffalo on Feb. 26, 1948, relating to withdrawal of Sustaining Member benefits,

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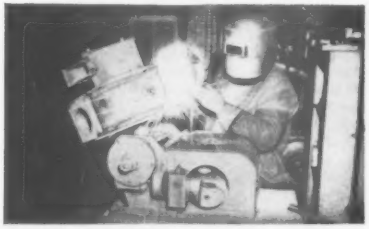

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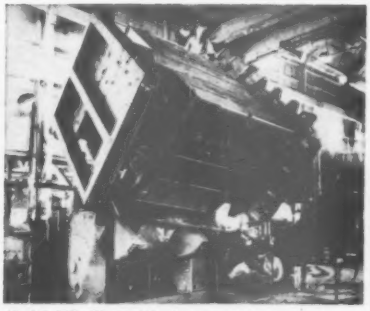

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that is, in furnishing gratis the annual bound volume of THE WELDING JOURNAL and copy of the SOCIETY's codes and standards as issued, be rescinded.

Educational Books

It was voted to request the Educational Committee to consider and report back to the Board of Directors on the possibility of the appointment of a subcommittee, with personnel and scope as follows:

Personnel: Composed of members who are engaged in educational activities with experience in the production and sale of educational books.

Scope: To explore industry's needs for welding educational books and sales possibilities of books listed in the Executive Secretary's communication of Mar. 7, 1949, as well as other books that may come to the attention of the subcommittee; and further, to supervise and have jurisdiction over the production and sale of welding educational books published by the SOCIETY so as to insure the success of this activity, financially and otherwise.

Progress Report on the 1949 Annual Meeting was presented to the meeting and was accepted with thanks and the Secretary was requested to express our gratitude to all responsible for assisting in effecting the satisfactory arrangements shown in this progress report.

It was reported that the SOCIETY had received from A.S.M., a further contribution of $75 representing the SOCIETY's share of exhibit rental in the 1948 Exposition.

By-Law Amendments

Amendments of by-laws submitted by Mr. Hill, a member of the Constitution and By-Laws Committee, in behalf of the Chairman of the Committee, were given most careful consideration. With the changes proposed at this meeting incorporated, the amended by-laws as given elsewhere were approved with recommendation for adoption by the Board of Directors.

TAC Recommendations

Following are the actions taken on recommendations of the Technical Activities Committee, as covered in memorandum dated Feb. 18, 1949, to the Board of Directors from the Technical Secretary and attached to the agenda of this meeting:

Proposed Standard Welding Terms and Their Definitions—On recommendation of T.A.C., it was voted to approve, as a full standard of the SOCIETY, Standard Welding Terms and Their Definitions and Master Chart of Welding Processes, prepared and submitted by the Committee on Definitions and Chart as a revision of the standard issued in 1942, subject to the necessary editorial corrections.

Expansion of Scope of A.W.S. Technical Committee Activities—Recommendation of T.A.C. for the expansion of scope of A.W.S. Technical Committee Activities, to include the soft soldering process, was considered. It was voted to postpone action on this recommendation until the next meeting of the Board of Directors to permit further study of this matter.

Revision to Rules for Welding Piping in Marine Construction—On recommendation of T.A.C., revision of the 1948 Rules for Welding Piping in Marine Construction, by adding item (4) under Par. 7b, reading: "Sleeve and socket joints may be welded without size limitations," was approved.

Appointment of A.W.S. Representative on Inter-Society Corrosion Committee of the National Association of Corrosion Engineers—Negative action was taken on T.A.C. recommendation that this appointment be not made as it was deemed advisable before action is taken, opportunity be afforded the President of the National Association of Corrosion Engineers to furnish T.A.C. with more complete information on the activity in question.

Revision to Rule 12, Rules to Govern Organization, Functions and Operations of Technical Committees of A.W.S.—On recommendation of T.A.C. and for reasons cited in memorandum dated Feb. 18, 1949, to the Board of Directors from the Technical Secretary, it was voted to approve revision to Rule 12 of Rules to Govern Organization, Functions and Operations of Technical Committees of A.W.S. The revised rule now reads:

"The Chairman and Vice-Chairman of a technical committee shall be elected for three-year terms. Neither officer shall be eligible, except by specific action of the Technical Activities Committee, or the Executive Subcommittee of the Technical Activities Committee, to serve two consecutive terms in the same office. The Technical Activities Committee shall regulate the election of technical committee officers so that approximately one-third of them are changed each year. Prior to

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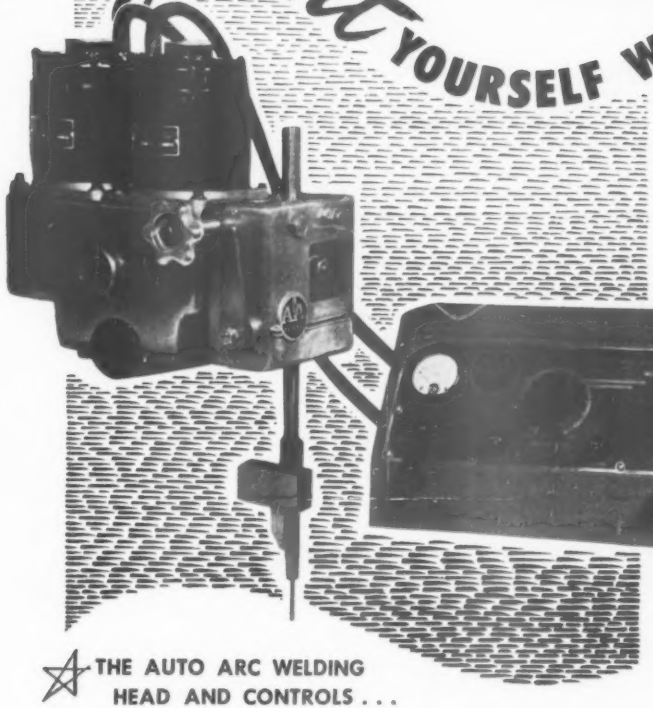
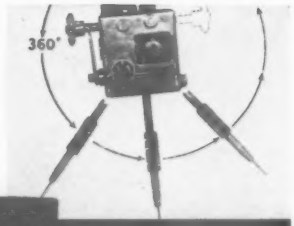
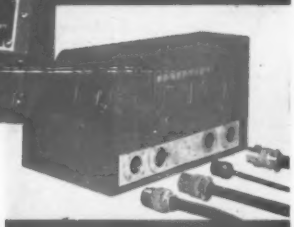
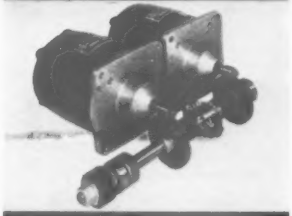




Wire guide mechanism can be rotated 360° about feed roll axis. Guide control knob may be mounted on either side of Head.



Interchangeable control panels have all external circuits connected by multiple conductor plugs. 8" x14" x8" cabinet weighs 19 lbs.



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expiration of officers' terms of office, the chairman of each technical committee shall arrange for an election of officers to serve for the ensuing two years. In case of failure of any technical committee to elect officers, it shall be the privilege of the Technical Activities Committee to designate the new officers."

Appointment of A.W.S. Representative on A.S.M. Handbook Committee—On recommendation of T.A.C., the appointment of C. H. Jennings as A.W.S. representative on A.S.M. Metals Handbook Committee, was approved.

Appointment of A.W.S. Representative on A.S.A. Sectional Committee on Standard for Drawings and Drafting Room Practice, Z14—The Executive Committee concurred in opinion of T.A.C. that A.W.S. representation on this Committee is unnecessary if participation in A.S.A. Sectional Committee Z32 on which A.W.S. has representation, covers properly the use of Standard Welding Symbols.

Assistant Technical Secretary—On recommendation of the Technical Secretary in conference with the Executive Secretary, and with the approval of T.A.C., it was voted to recommend to the Board of Directors for confirmation at its May 13, 1949, meeting, advancement of J. I. Medoff from the post of Technical Assistant to the Technical Secretary and *Handbook* Editor, to the post of Assistant Technical Secretary.

Death of George Herren

In a memorandum distributed at this meeting, and attached to minutes of absent members, attention was drawn to the sudden death of Mr. Herren, a founder member and Secretary of the Columbus Section, who had served the Society faithfully for the past eleven years. Acting President Fraser was empowered to appoint a Committee of two to draw up suitable Memorial Resolutions for presentation at the next meeting.

Correction Notice

In an article entitled, "Trends in Resistance Welding Here and Abroad," prepared by Hensel and Holt of the P. R. Mallory Co., which was published in the November 1948 issue, there appeared illustrations of three welding machines of British manufacture. Figures 2, 3 and 4 were obtained through the courtesy of the Metropolitan-Vickers Electrical Corp. of England and this courtesy is hereby acknowledged.

Bound Volume 1948

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Revisions to A.W.S. By-Laws

The following revisions to the A.W.S. By-Laws have been submitted by the Constitution and By-Laws Committee and were approved by the National Executive Committee on Mar. 7, 1949.

ARTICLE VIII, Section 1. List of Officers. Delete the words "an Executive Secretary."

ARTICLE VIII, Section 8. Executive Secretary. Delete. Renumber Sections 9 to 11, inclusive, as 8 to 10, inclusive.

Add a new Section to Article VIII as follows:

ARTICLE VIII, Section 11. Secretary Emeritus. The Board of Directors may from time to time, in its discretion, appoint any past Secretary of the SOCIETY "Secretary Emeritus," for such term and with compensation and duties as the Board may designate.

ARTICLE IX, Section 1. Nominations. Nominations for officers except Honorary Directors, Secretary, Assistant Secretary and Assistant Treasurer, shall proceed as follows: (balance no change).

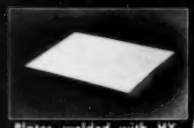
ARTICLE X, Section 8. Duties of Secretary. Delete.

ARTICLE X, Sections 9 to 12. Renumber as Sections 8 to 11, inclusive.

ARTICLE X, Section 7, revise as follows:

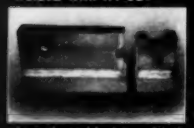
Duties of Secretary—Sub-Section (*a*)

A Few of the Many Applications



Plates welded with HY-LO, enameled without annealing.

Broken plow share welded with HY-LO.



Two shear blades welded with HY-LO.

Section of alloy pipe welded in three positions with HY-LO.

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Delbert Craven

We fabricate many different types of cranes ranging up to 300 tons capacity. Most of these structures involve heavy, boxed-up sections on which arc blow seriously limited the amount of current and the welding speed that could be used. By installing 500-amp. AC "Fleetwelders" for this work, we have eliminated arc blow, and the operators are now able to boost their welding current from 300 to 385 amperes, resulting in 25% faster welding. Moreover, the welds are of higher quality and easier to make.

The crane girder shown in Fig. 1 is typical of the kind of weldment now being fabricated in our shop. The top and bottom plates are $\frac{7}{8}$" plate, fillet welded to $\frac{5}{16}$" side plates with large diameter $\frac{1}{4}$" "Fleetweld 7" electrodes. Many of the welds on this 85 ft. crane girder are single pass $\frac{5}{16}$" fillets requiring heavy sustained welding at high currents (Fig. 3).

Substantial savings in idle power losses are further helping to cut our costs on these jobs. Where the idle factor is high, such as leaving the welder connected to the line while fitting up parts, considerable cost savings are made since the "Fleetwelders" draw far less current from the line than the motor driven equipment formerly used.

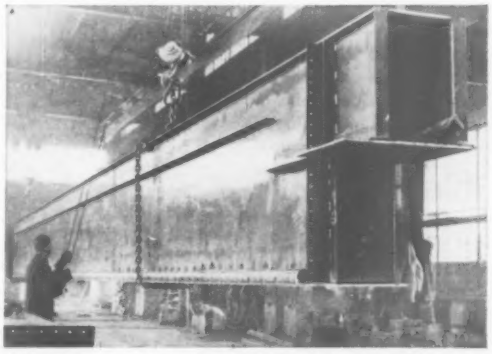

Fig. 1. Girder for 60-ton capacity crane AC weld fabricated with the new Lincoln "Fleetwelder." Top and bottom plates are $\frac{7}{8}$" steel . . . sides are $\frac{5}{16}$" plate. Girder is 85 ft. long, 76 in. high and 28 in. wide . . . weighs 20 tons.

A comparison of the all welded crane girder with similar size riveted designs shows a saving of 20% in weight. This weight saving is largely the result of eliminating connecting members and rivets by arc welding.

Fig. 2. Setting correct welding current with Continuous Current Control on the 500-amp. Lincoln "Fleetwelder" AC arc welder. "Fleetwelder" has exclusive "Arc Booster" that makes arc striking easy on all types of work.

Fig. 3. Fillet welding rope guard of 5" pipe to bottom plate with $\frac{1}{4}$" "Fleetweld 7" electrode and using 385 amps. welding current. Fillet welds are single pass $\frac{5}{16}$" continuous and intermittent.

The above is published by **THE LINCOLN ELECTRIC COMPANY** *in the interests of progress.*
For further information on the "Fleetwelder," write for Bul. 366. The Lincoln Electric Company, Dept. 95, Cleveland 1, Ohio.

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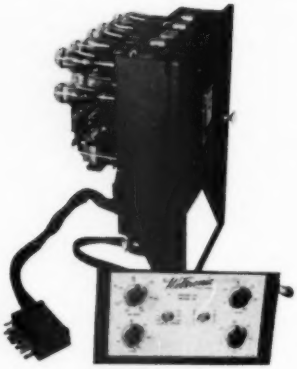

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delete the word "Executive," balance no change.

Sub-Sections (*b*) to (*h*), inclusive, no change.

(*i*) He shall attend all meetings of the Society, of the Executive Committee and of the Board of Directors; prepare the business therefor; and duly record the proceedings thereof.

(*j*) He shall see that all monies due the Society are carefully collected, and without loss transferred to the custody of the Treasurer.

(*k*) He shall carefully scrutinize all expenditures and exert every effort to secure economy in the administration of the Society and shall personally certify the accuracy of all bills or vouchers on which money is to be paid.

(*l*) He shall have charge of the books of account of the Society and shall furnish monthly to the Treasurer a statement of receipts and expenditures under their several headings and also a statement of monthly balances and shall furnish from time to time such other statements as may be required.

(*m*) He shall conduct the official correspondence of the Society and keep complete records thereof.

(*n*) He shall have charge of the Society's rooms and all property of the Society.

(*o*) He shall give the Society a bond in a sum, and with one or more securities as required by, and satisfactory to, the Board of Directors for the faithful performance of the duties of this office and the restoration to the Society in the case of death, resignation or removal from office of the Secretary, of all books, papers, vouchers, money or other property of whatever kind in the possession of the Secretary, belonging to the Society. The cost of the bond shall be borne by the Society.

Article X, Section 11. Duties of Assistant Treasurer.

(*b*) The Assistant Treasurer shall be, ex-officio, a member of the Finance Committee. (Delete the balance.)

Article XII. Change the title from "Committees" to "Standing Committees."

Article XII, Section 2. Finance Committee. A Finance Committee, selected from members of the Board of Directors, which shall pass upon all expenditures, prepare the next year's annual budget for submission to the Board of Directors at the Board's first meeting in the new fiscal year and have general charge of the finances of the Society. The Treasurer shall be chairman of the Finance Committee and the Assistant Treasurer shall be, ex-officio, a member of the Committee.

Article XII, Section 6. Publication Committee. Change the name of this Committee from "Publication Committee" to "Welding Journal Committee." Substitute for the present wording of Section 6 the following wording: "Welding Journal Committee. The Welding Journal Committee shall solicit and edit papers for, and supervise, the publication of The Welding Journal in accordance with established rules governing the publication of the Society's Journal as approved by the Board of Directors."

Article XII, Section 10. Technical Activities Committee. Substitute for the

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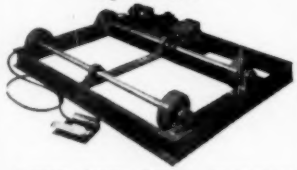

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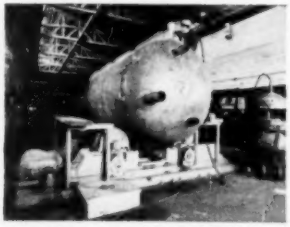

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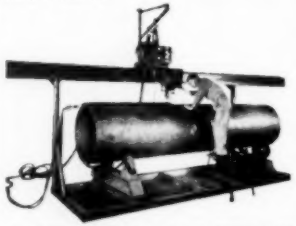

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present text of this Section, the following wording: "A Technical Activities Committee which shall consist of the Chairmen of all the Technical Committees of the Society and not more than three members-at-large to be appointed annually by the President, and ex-officio, the Chairman of the Public Relations Committee. It shall have a Chairman and a Vice-Chairman, who shall be members of the Society and shall be elected by the Committee's membership, but not necessarily from its own ranks. These officers shall serve for a period of three years. The Technical Secretary of the Society shall be the Secretary of this Committee."

The scope of this Committee shall be: "To organize and administer the activities of the technical committees of the Society in accordance with the 'Rules to Govern Organization, Functions and Operations of Technical Committees of the American Welding Society;' to nominate and administer the activities of official representatives of the Society on technical committees of other societies in accordance with the 'Guide for the Appointment and Functioning of Representatives of the American Welding Society on Technical Committees of Other Societies;' to promote the standards of the Society through the A.W.S. technical committees and A.W.S. representatives on technical committees of other societies; to act in an advisory capacity to the Board of Directors in respect to technical matters; to administer the preparation and review of technical regulatory requirements of governmental and other code-writing bodies and the cooperation with these bodies in any other reasonable manner toward the elimination of unnecessarily restrictive welding requirements through the promotion of the Society's standards; by direct action jointly with the Public Relations Committee or by recommendation to the Board of Directors, to participate in public relations matters of a technical nature affecting the interest of the members of the American Welding Society; to promote the technical advancement of welding through any other means as may appear expedient to the Board of Directors to insure the best interest of the welding industry."

"The Technical Activities Committee shall present a report of its activities during the past year to the Society at its Annual Meeting."

Article XII, Section 11. Technical Committees. Delete this Section from Article XII. Renumber Sections 12 to 23, inclusive, to Sections 11 to 22, inclusive.

Article XII, Section 13. (New Section 12) Committee on Awards. A Committee on Awards consisting of five members each serving for a period of five years, one member retiring each year. The Chairman of the Committee shall be the member senior in service, provided that no member during his five-year term of membership shall be eligible to serve more than one year as Chairman, in addition to any part of the unexpired term of the previous Chairman. In the case of a vacancy, the Board of Directors shall appoint a member to fill the unexpired term of the retired member, but he shall not inherit the seniority of the retired member. It shall be the duty of this Committee to make the awards and nominate those to present honorary lecturers at the Annual Meeting and to arrange for the presentation of such medals, certificates or other awards as may be authorized by the Board of Directors. (Delete the last paragraph.)

Article XII, Section 15. (New Section 14) Committee on Permanent Funds. Change the name of this Committee to "Reserve Funds Committee," and revise as follows:

"A Reserve Funds Committee of five members, each to serve for five years, one member of which shall retire each year. The Chairman of the Committee shall be the member senior in service, provided that no member during his five-year term of membership shall be eligible to serve more than one year as chairman, in addition to any part of the unexpired term of the previous Chairman. In the case of a vacancy the Board of Directors shall appoint a member to fill the unexpired term of the retired member, but he shall not inherit the seniority of the retired member. The Treasurer of the Society shall be, ex-officio, a member of this Committee.

"Funds turned over to this Committee by the Board of Directors shall be in its custody for safekeeping and the Committee is authorized to hold these funds in cash and/or investments approved by the State of New York for Savings Banks and Insurance Companies. All acts of the Committee shall require the favorable vote of at least four members of the Committee.

"No disbursements shall be made from these funds except on approval of at least two-thirds of those present at a meeting of the Board of Directors called for the purpose, and at which a quorum is present, and the concurring approval of two-thirds of the Reserve Funds Committee. Should the Committee fail to approve by a two-thirds vote and so advise the Board in writing giving its reasons for its failure to approve, then the question shall be submitted for letter ballot to all the members of the Board of Directors. The letter ballot must be accompanied by a copy of the minutes on this subject of such Board meeting and by a copy of the written report of the Reserve Funds Committee to the Board. Two-thirds favorable vote of the entire Board membership on the letter ballot shall be necessary to authorize the disbursement.

"The Committee shall keep full and accurate accounts of receipts and disbursements in books belonging to the Society, and shall render a financial statement to the Board of Directors annually, or more often if requested."

Article XII, Section 16. (New Section 15.) Public Relations Committee. Substitute for the present wording of this Section, the following:

"A Public Relations Committee not to exceed eight appointed members and, ex-officio, the Secretary of the Technical Activities Committee which shall handle the relations of the Society to the public, exclusive of matters specifically assigned to other committees. Its duties shall include the studying of Municipal, State and Federal legislative acts or proposals that

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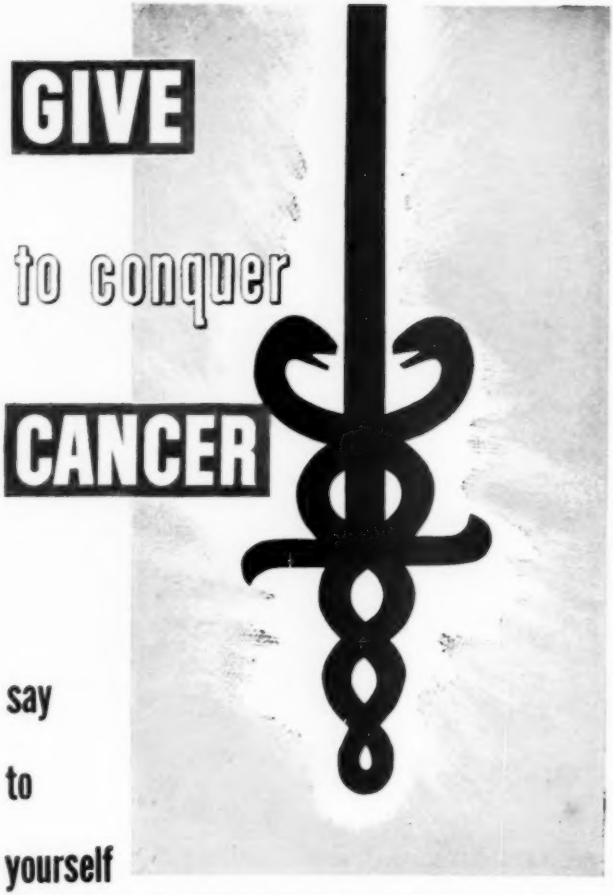

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affect the Society or the art of welding and the making of appropriate recommendations in order to insure the best interests of the welding art."

Article XII, Section 18. (New Section 17.) Convention Committee. After the words "Secretary of the Publicity Committee," add "the Chairman of the Educational Committee."

Article XII, Section 23. (New Section 22.) Term of Committees. Delete the second sentence of the present text of this Section.

Add a new Article XIII. "Technical Committees. Technical Committees, not limited in number, shall be established and shall operate in accordance with the latest revision of 'Rules to Govern Organization, Function and Operation of Technical Committees of the American Welding Society under the jurisdiction of the Technical Activities Committee."

Renumber Articles XIII, XIV, XV, XVI, XVII, XVIII, XIX, XX to XIV, XV, XVI, XVII, XVIII, XIX, XX, XXI.

Article XVII. (New Article XVIII.) Section 1. Fiscal Year—revise as follows: "The fiscal year of the Society shall commence on September 1st and end August 31st."

Article XX. (New Article XXI.) Amendments. Section 1. In the last sentence insert the word "eligible" before the last two words "voting membership."

Other By-Law Amendments

The Constitution and By-Laws Committee suggests the following additional revisions which have not been submitted to the National Executive Committee. These revisions all relate to the appointment of the National Nominating Committee.

Article VI, Section 6. District Nominations. Before March 1st, the District Vice-President, with the approval of the District Executive Committee shall appoint a District Nominating Committee consisting of a member from each Section in the District. The District Nominating Committee shall report to the National Secretary not later than the 10th day of May of that year, the name of the nominee they have selected for the National Nominating Committee to serve for the following year and for District Vice-President, when a District Vice-President is due for election, together with the written acceptance of the nominees included in the report.

Independent nominations may be made by petition of twenty-five (25) or more qualified voters, sent to the National Secretary not later than July 1st; such petitions for the nomination of District Vice-Presidents and of District Representatives on the National Nominating Committee shall be signed only by qualified voters within the District concerned. (See Article IX, Section 1.)

Each year the National ballot for Nomination of Officers shall include the names of the District Vice-Presidents and of the members of the National Nominating Committee nominated by the District Nominating Committees and names of nominees nominated by petition in accordance with the above provision.

Only District members, qualified to vote, shall be eligible to vote for District

POPULARIZING THE WELDING JOURNAL

The Publication Committee has instructed the Editor to add a special section in The Welding Journal each month, under some departmental heading as "Practical Welder and Designer." The nucleus of this special section will be one article each month of not more than four pages nor less than two which will give practical information on how to do a specific job, covering as many of the following topics as possible:

1. An exact procedure with illustrations of how to do the job.
2. Detail information as to design.
3. Full information on welding procedure or fabrication details.
4. Testing and inspection.

The Publication Committee has set aside $50 each month for payment of accepted articles of this nature. They should be written preferably by one who has followed the specific application in detail. Clear photographs or charts will be helpful and should be utilized.

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PRODUCTION WELDING—Ampco's Phos-trode was selected for the fabrication of these bronze water-heater tanks after exhaustive tests of other rods and welding techniques. With Phos-trode electrodes, there was no deposit and fusion-zone cracking. Minimum spatter reduced cleaning time; freedom from porosity and pitting. All tanks met hydrostatic pressure tests without trouble.

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Vice-Presidents or for District representatives on the National Nominating Committee.

ARTICLE VI, Section 7. Vacancies. The Executive Committee of each District shall have the power to fill a vacancy in the office of Vice-President of that District and of that District's representative on the National Nominating Committee for an unexpired term whenever such vacancy occurs.

ARTICLE IX. Nomination and Election of Officers and Representatives.

Section 1. Nominations. Nominations, except for Honorary Directors, Secretary, Assistant Secretary and Assistant Treasurer, shall proceed as follows:

(*a*) Nominations for District Vice-Presidents and for District Representatives on the National Nominating Committee shall be made by the District Nominating Committees. See Article VI, Section 6. The National Nominating Committee shall select nominees for the other offices falling vacant. See Article XII, Section 7. The names of nominees for each office shall be published in the June issue of THE WELDING JOURNAL of the AMERICAN WELDING SOCIETY.

(Balance—no change)

ARTICLE XII. Standing Committees. Section 7. National Nominating Committee. A National Nominating Committee consisting of eight members. The Committee shall consist of a Chairman, who shall be a Past-President of the SOCIETY, and seven District Representatives who were elected the previous year to the National Nominating Committee. Announcement of the personnel of the Committee shall be made through publication in THE WELDING JOURNAL on or before March 1st. The Committee shall deliver to the National Secretary in writing on or before the 10th day of May of that year, the names of its nominees for the various elective offices next falling vacant with the written acceptance of each nominee. (District Vice-Presidents and District Representatives on the National Nominating Committee shall be nominated by each District Nominating Committee. See Article VI, Section 6.) This Committee shall also canvass the nomination ballots and certify the result to the National Secretary.

(If these later revisions relating to the National Nominating Committee are adopted, Article IX heading and Section 1 will replace the wording given in the forward part of this report.

Copies of The Welding Journal

One of our members in England is desirous of obtaining copies of the February 1938 and May 1940 issues of THE WELDING JOURNAL. Any member who has a copy of either or both of these issues, and wishes to sell it, please get in touch with D. J. W. Boag, Managing Director, Rockwell Ltd., Commerce Way, Croydon, Surrey, England.

Annual Meeting

The Thirtieth Annual Meeting of the AMERICAN WELDING SOCIETY will be held at the Cleveland Hotel, Cleveland, Ohio, week of October 16, 1949.

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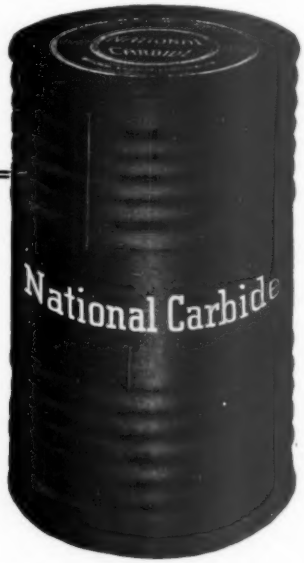

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NEWS OF THE INDUSTRY

Clapp Joins Battelle

Melvin C. Clapp, a graduate in welding engineering from Ohio State University, has joined the staff of Battelle Institute, Columbus, Ohio. Mr. Clapp is a member of the AMERICAN WELDING SOCIETY.

Banner Mfg. Co.

David V. Uihlein has acquired the Banner Mfg. Co., 4961 N. 29th St., Milwaukee 9, Wis., and will act in the capacity of executive director.

Formerly known as Banner Products Co., the new organization plans to increase distribution and service on their line of Banner Resistance Welders and Brazers. Their present program calls for new design changes and improvement in the Banner line, plus the addition of new products in the welding field.

J. R. G. Harris is handling the sale of Banner welders in the State of Wisconsin and other territories are rapidly being developed. *Arthur Kranitz* remains in charge of production, and the technical staff is being augmented to better serve industry.

Linde Expands Facilities at Albuquerque

A new plant, producing Prest-O-Lite acetylene at Albuquerque, N. Mex., will begin operations on Mar. 7, 1949, according to an announcement made by The Linde Air Products Co., a Unit of Union Carbide and Carbon Corp. This plant will supplement the facilities of an oxygen filling station which, for about seven years, has provided industries in this area with a convenient source of Linde oxygen. A warehouse for the distribution of Union Carbide is also located on the plant premises. The address of the plant is 2520 S. Second St., P. O. Box 805. Rail facilities are provided by the Santa Fe Railroad.

Senator Karl Mundt Addressed International Acetylene Association

The Honorable Karl E. Mundt, United States Senator from South Dakota, addressed the opening luncheon of the International Acetylene Association's Convention in Pittsburgh, on April 25th. This is the 51st year of the Association's service to its members and to the public. The luncheon was held at the Hotel William Penn.

The presentation of the James Turner Morehead Medal to Herman Van Fleet of Air Reduction Sales Co. was another feature of the luncheon. This is the Association's highest award and is awarded annually by the International Acetylene Association to the person or persons who, in the judgment of its Officers and Board of Directors, have done most to advance the industry or the art of producing or utilizing calcium carbide or its derivatives. Mr. Van Fleet received the Medal in recognition of his leadership and direction in the production of acetylene and oxygen, and in the development of equipment for their use. R. B. Swope, President of the Southern Oxygen Co., Washington, D. C., made the presentation.

The first technical session of the Convention was held at the Hotel William Penn at 2:00 P.M. on Monday, April 25th, following the luncheon. These papers were presented:

1. "Use of Oxyacetylene for Scarfing and Gouging," George Mersot, General Foreman, Inland Steel Co., East Chicago, Ind.

2. "Flame-Hardening," John T. Howat, President, Pittsburgh Metal processing Co.

3. "Applications of the Oxyacetylene Flame for Heating, Straightening, and Forming," F. H. Dill, Welding Engineer, American Bridge Co., Ambridge, Pa.

The program for Monday was concluded with the annual business meeting and election of officers. No evening sessions were planned.

Sessions on Tuesday, April 26th, moved to Mellon Institute. The program opened at 10:00 A.M. in the Auditorium. Dr. E. A. Holbrook, Dean of the School of Engineering, University of Pittsburgh, acted as General Chairman for the day. Students and faculty members from nearby schools and universities, and representatives from industry had an opportunity to hear talks on the background and development of the oxyacetylene industry, on the chemistry of acetylene and on the applications of oxyacetylene processes in industry. Papers presented at the morning session were:

1. "Background and Development of the Oxyacetylene Industry," Alvah Small, Vice-Chairman, Underwriters Laboratories, Inc.

2. "Acetylene Chemistry," C. J. Herrly, Sales Manager, Niacet Chemicals Division, United States Vanadium Corp.

3. "Explosion Pressures in Industrial Piping Systems," J. B. Smith, Engineer, Factory Mutual Laboratories.

The afternoon session on Tuesday, April 26th, scheduled for 2:00 P.M. presented three papers on applications of oxyacetylene cutting. "Cutting of Stainless Steel" was discussed in an important paper, and "Heavy Cutting in the Steel Mill" described by L. P. Elly, Welding Supervisor of Bethlehem Steel Co., Bethlehem, Pa. F. B. Rykoskey, Supervisor of Shops of the Baltimore and Ohio Railroad Co., spoke on "Shape-Cutting in Railroad Shops."

All of the technical sessions and luncheons of the Convention were open to engineers, executives, students, teachers and the general public. There was no registration fee.

Railroad Fair

Summer can't be far off! The national Railroad Fair, which ranked last year as the most heavily attended attraction on the country's vacation program with a record attendance of 2,500,813, is beginning to stir on Chicago's lakefront for a repeat presentation scheduled to open June 25th.

Timed to take advantage of spring thaws, workmen will move in this week to transform the fairgrounds from winter rest to a gigantic spectacle designed to outdraw last year's 50-acre success.

By opening day all plans for this year's dramatic new entertainment features, displays and exhibitions will be translated into reality, according to Major Lenox R. Lohr, president of the railroad industry's exposition.

British Industries Fair: 1949

The growing importance of pressworking as a process of engineering production is made clear by many of the exhibits to be displayed at the Birmingham Section of the British Industries Fair (Earls Court and Olympia, London; Castle Bromwich, Birmingham, May 2–13). Presses of many types will be there, ranging from high-speed machines with automatic feeds giving many thousands of stampings an hour, to machines of 500 tons capacity suitable for deep drawing or the bending of heavy steel sections. Exhibiting firms make considerably heavier machines, and naturally there are difficulties in the way of showing them at the exhibition.

Special attention should be paid to the high-frequency induction heating equipment on show. There is no doubt that for repetition hardening and annealing operations, and for mass production brazing and soldering this type of heating offers enormous possibilities. It is one that is being developed and exploited rapidly by United Kingdom engineers.

Some of the latest equipment for all welding processes will be demonstrated. In view of the increasing use of welding as a means for fabricating all manner of structures, from light weight instrument parts to bridges, this equipment forms an important section of the Fair.

Electric arc-welding equipment covers hand-welding sets (including engine-driven sets for use where current from the mains is not available) and automatic equipment using continuous electrodes and suitable for straight and circumferential seams.

Closely allied to the gas-welding equipment to be shown will be oxygen-cutting machines, the largest of which are capable of cutting through steel several feet thick. These machines will follow accurately a drawing or template, and they offer an economical method of cutting all manner of shapes from steel plate, whether in small or large quantities.

Resistance welding gains popularity as a repetition method of joining metal parts. The general-purpose machines used for spot, projection, butt and seam welding are capable of accommodating a wide variety of jobs, while special-purpose machines prove themselves economical where the number of parts to be welded justifies installation of the machines.

Jigs, manipulators, holding down magnets and other accessories for aiding the welder will be shown also.

Welding is much used for building up worn surfaces of machine parts, and is especially useful for the hard surfacing of metal parts subject to much abrasion, such as digger teeth, and the lips of grabs.

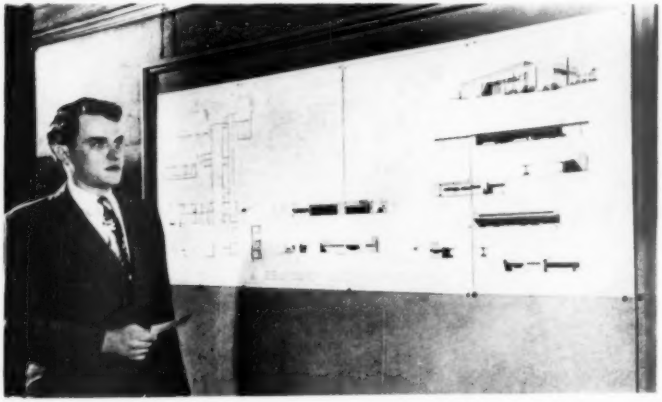
Other methods of depositing metals will be demonstrated, deposition being performed with the object of building up worn parts or of imparting good wearing or good corrosion-resisting properties to metal surfaces.

Metal spraying is one process employed. Metal to be deposited is fed through a gun by which it is heated to melting point and atomized, the resultant metal particles being blown on to the surface to be covered. The technique can be adapted to deposit metals on metals, or metals on non-metallic objects. One interesting application of the technique is that of aluminizing for resistance to high temperature.

Scholarship Won by Proposed Plans for Welded Railroad Station

The plans for a proposed suburban railroad station which called for the use of a welded structure won for James Edgar Steed, Washington Court House, Ohio, one of four $250 scholarships established at the University of Cincinnati by The James F. Lincoln Arc Welding Foundation. Steed, a third-year cooperative student in the Department of Architecture of the University's College of Applied Arts, won a competition for the scholarship that was open to the pre-junior members of the department.

The four Foundation scholarships, known as "The Alan R. Cripe-Lincoln Arc Welding Foundation Scholarships," were established at the University when



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Cripe, now a junior in the College of Applied Arts, won first award in the 1948 competition in the Foundation's Annual Engineering Undergraduate Award and Scholarship Program. Dean Pickering of the University has announced that one scholarship will be awarded each year to an outstanding member of the pre-junior class in the Department of Architecture.

A native of Washington Court House, Steed served with the armed forces during World War II. He is on the Dean's list of students ranking among the top 10% scholastically in their College of Applied Arts classes. In connection with his co-operative course in architecture, Steed is employed by George E. McDonald, a registered architect of Cincinnati.

Under the Cincinnati plan of cooperative technological education, founded at the University in 1906, architectural students spend alternating periods of study on the campus and of practical training on the job.

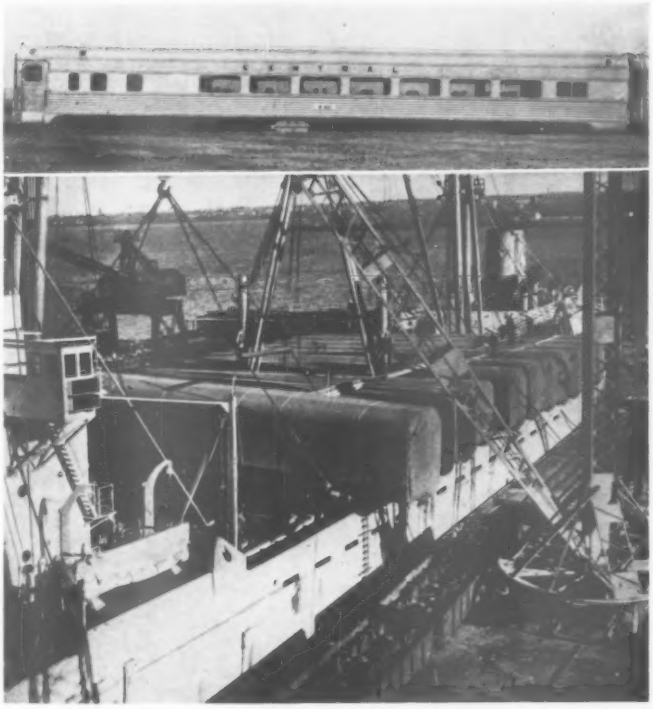
23 Railroad Passenger Cars Shipped by Budd to South America

A unique loading operation was completed at Port Richmond when the last of 23 Budd-built, all-stainless steel railway passenger cars was lowered into place. With six 72-ft. cars lashed below her hatches and seventeen 85-ft. cars athwart her deck, the Norwegian freighter, S.S. *Beljeanne*, prepared to sail nonstop to Rio de Janeiro where the cars will be put into immediate service on the Central Railway of Brazil.

One unusual stevedoring feat was the lowering of six cars into the holds as there was less than 1-ft. clearance between the ends of the car and the hatch opening. The first two cars were lowered onto greased skids on the hold's floor and then pushed to each side to make room for two more in the center.

The cars on deck overhang approximately 8 ft. on each side. Each car is covered with a tarpaulin and securely fastened in place with special fittings.

Another interesting activity which preceded the loading was the changing of car trucks. Built at The Budd Co.'s Red Lion plant in Northeast Philadelphia, the cars were run over standard gage, 56½-in. tracks to the pier. At the pier, 800 ft. of special track, 63 in. wide, had been laid to accommodate the width of trucks used in Brazil. Each car was lifted from its standard trucks and lowered onto the wider trucks before car and truck were loaded on the ship.



The cars, including bedroom sleepers, diners, coaches, baggage, mail, lounge-observation and a business car are similar to those The Budd Co. has built for the crack streamliners of the leading United States railroads. They are equipped with the latest air-conditioning and fluorescent lighting equipment and have modern interior decorations.

The new cars will be operated between Rio de Janeiro, São Paulo and Belo Horizonte, the leading cities of Brazil, and will serve the most important industrial sections of the country. The overnight run between Rio de Janeiro and São Paulo is one of the most heavily traveled routes in Brazil. Some of the cars will replace equipment now in use on the Cruzeiro do Sul.

Some coaches have a capacity of 76 passengers; others carry 56 passengers and have deluxe lounges for both men and women. The sleeping cars each contain 12 double bedrooms, giving each a capacity of 24 passengers.

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A. O. Smith Receives Award

A Certificate of Merit from President Truman was presented recently to William C. Heath, president of the A. O. Smith Corp. The presentation was made in Milwaukee by Maj. Gen Paul L. Williams, commanding officer of the 10th Air Force. The certificate was awarded for work that was done by A. O. Smith during the war in the development and production of welded hollow steel propeller blades. In addition to the blades, A. O. Smith was a large pro-

ducer of bombs, torpedo air flasks and landing gear for bombers. The company made all of the B-29 landing gear.

National Welding Supply Association

This Association with offices at 505 Arch St., Philadelphia 6, Pa., has announced its plans for the Spring Meeting to be held at the Hotel Gibson, Cincinnati 1, Ohio, on Wednesday, Thursday and Friday, May 11, 12 and 13. Hotel reservations may be made by writing to the Hotel Gibson, Cincinnati 1, Ohio, attention Miss Ann Kroger. The Program starts off on the evening of Tuesday, May 10th, with a dinner meeting of the Executive Committee and the Board of Directors. Wednesday morning includes an address by the Mayor of the city of Cincinnati, introduction of members and guests, and the annual address of the President, Mr. Ralph E. Chase of the Chase Welding Supply Co., Inc. The feature of this occasion will be an address by Mr. James Lincoln of The Lincoln Electric Co., on "Welding and Its Future."

In the afternoon there will be a plant visitation to the Armco Steel Corp., Middletown, Ohio. Buses will be provided. The Thursday morning session includes Amendment to the Constitution and By-Laws and a report on the activities of the Association by Mr. Thomas A. Fernley, Jr., Advisory Secretary. There will also be a report by the Membership Committee by Mr. W. R. Boyd, Chairman of this Committee. This session also includes an address on "Increasing Wholesale Salesmen's Effectiveness," by James H. Davis, Professor, College of Commerce and Administration, Ohio State University. This will be followed by a luncheon in the Ballroom.

In the afternoon there will be discussion periods as follows:

"Our Experience with a Perpetual Inventory System," R. P. Tarbell, President, Scott-Tarbell, Inc., Cleveland, Ohio.

"Advertising Budgets and the Most Effective Types of Advertising Media That Can Be Utilized by the Average Welding Supply Distributor," W. A. Rice, Sales Manager, Virginia Welding Co., Charleston, W. Va.

"Our Methods of Compensating Salesmen," J. W. Albiston, Maine Oxy-Acetylene Supply Co., Auburn, Me.

"What Method or Methods Can Be Used to Determine Whether Salesman Are Paying Their Way," Allen H. Young, Independent Distributing Co., St. Joseph, Mo.

"Are the Gross Margins We Are Receiving Adequate to Cover Our Operating Costs," W. J. Bentley, Bentley Sales Co., Milwaukee, Wis.

"The Basis on Which We Sell the Small Store Which Resells Replacement Parts," Howard Proctor, Acme Welding Supply Co., Houston, Tex.

An informal dinner will be held in the Ballroom with an address by Mr. F. W. Fiesel, Business Manager of *The Cincinnati Post* on "Standards of Excellence." The Friday morning session includes three addresses as follows:

"Fundamentals of Selling," Roy Poe, Tweco Products Co., Wichita, Kan.

(*Continued on page 509*)

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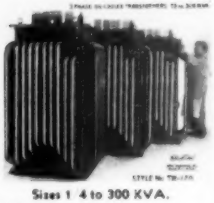

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If you are not already familiar with the codes, standards and specifications of the American Welding Society as well as the educational books, ask the Technical Representative (Liaison Officer) of your Local Section for a free copy of Bulletin 101 describing these publications. Also ask about the special discounts to members. If you prefer, write directly to AWS Headquarters.

It is easy to keep informed through American Welding Society technical publications.

They will help you.
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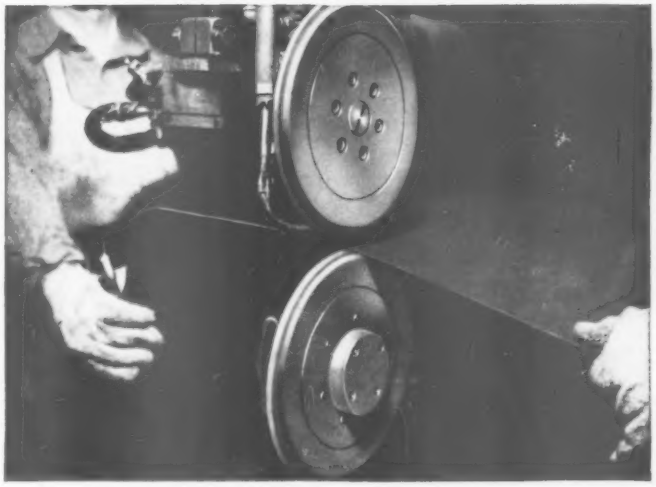

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NEW LITERATURE

Studwelding Equipment

Parts and accessories, for use with the Nelson studwelding gun, are identified and priced in a new 8-page bulletin. Items include special leg attachments, adaptors, spark arrestors and a number of complete accessory kits for special purpose applications. Write Nelson Stud Welding Division of Morton Gregory Corp., Lorain, Ohio.

Hard Facing by Welding

Hard Facing by Welding, by M. Riddihough, M. Met., A.R.I.C., F.I.M., was published on Feb. 8, 1949, at 8*s.* 6*d.* (postage 4*d*) by The Louis Cassier Co. Ltd., size D8vo (8¼ x 5½ in.). 127 pages, illustrated with over 81 photographs and diagrams. Cloth bound with jacket.

Every engineer knows that machines wear out; and a constant pre-occupation in every industry is the repair and replacement of worn parts. In this connection one of the most important uses of welding is the reclamation of worn components, specialized hard-facing rods and techniques having been evolved for this purpose.

This book (the first devoted solely to the subject) enables the welding and maintenance engineer to tackle efficiently the job of hard facing every type of metal. It is intended as a practical manual covering every stage of the process—design of component, choice of hard-facing alloy and technique of depositing, inspection and finishing methods.

The author is a recognized authority on the subject and has included sufficient technical information to enable the production engineer—or the operator—to appreciate and control the procedures.

The book is illustrated by 81 photographs and diagrams; there are 24 tables for reference and the appendix contains details of both English and American hard-facing materials.

Contents include: Hard-facing Rods and Their Development, Designing the Deposit, Designing for Specific Jobs, Characteristics of the Metals Commonly Used for Blanks, Preheating and Cooling, Heat Treatment for Hard-facing Various Types of Metals, Equipment and Jigs for Hard-facing, Hard-facing Techniques, Inspecting, Machining and Grinding the Deposit, Estimating and Planning. In the Appendix: Conversion Tables, Oxidation and Corrosion Resistance of Some Common Metals, Steel Specifications, Proprietary Hardfacing Rods: British, Proprietary Hardfacing Rods: American, Index.

Isotopes and Their Application in the Field of Industrial Materials

The 1948 A.S.T.M. Edgar Marburg Lecture "Isotopes and Their Application in the Field of Industrial Materials" by Dr. Paul C. Aebersold, Chief of the Isotopes Division, Atomic Energy Commission, has been published in the form of a 28-page booklet.

Dr. Aebersold, after some general comments pointing to the significance and interrelation of atomic energy and industrial materials, where he states among other things that science and industry are mutually dependent for progress and support and are stimulating to each other, discusses general research dividends, useful atomic power, induction of chemical and physical effects, and finally in some detail the applications of radioactive and stable isotopes. He points out that radioisotopes of most of the elements can now be made in the atomic pile and that production at Oak Ridge is sufficient to meet our domestic needs with some over.

The usefulness of radio isotopes, essentially, comes from two facts—first, they exhibit the same chemical behavior as the stable species of the elements, and secondly, they emit radiations which will determine their identity and location. The author covers isotope properties, production and measurement, with pertinent references to facilities and safety precautions. There is, also, a section devoted to the basis for isotope applications. Quite a portion of the lecture covers the use of these materials as tools for analysis with numerous specific applications. There is discussion of stable isotopes, and the lecture closes with general conclusions.

Copies of this 28-page booklet, in heavy paper cover, can be procured from A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa., at $1.00 each.

Ampco News

High pressures and extremely heavy loads are overcome by using overlays of Ampco-Trode. The complete story of this tough problem encountered by Northwest Lumber Mills and how Ampco-Trode succeeded in solving it is told in the first quarter issue of the *Ampco Welding News*. Also, learn how a Portland, Ore., fabricator successfully welded water-heater tanks of silicon bronze with Phos-Trode; how cast-iron valves functioning under corrosive and severe load service were successfully overlayed with Ampco-Trode; why a Belgium street railway uses Ampco-Trode "a.c."-rod to repair their tracks.

Other articles tell of the use of Beryl-Trode in rebuilding resistance welding jaws and how Ampco-Trode played a prominent part in the manufacture of synthetic alcohol from corn cobs.

Copies of this interesting and informative issue are available upon request. Write Ampco Metal, Inc., Dept. WN-1, Milwaukee 4, Wis.

Electrode Booklet

The Champion Rivet Co., Cleveland 5, Ohio, has issued a booklet "How to Choose and Use the Correct Electrode." Booklet will be forwarded without charge to all who apply for it.

Hose Connection

A new illustrated condensed catalog just published by Hose Accessories Co., Philadelphia, describes the complete line of LE-HI hose couplings, hose clamps, air valves and manifolds.

Copies of the new LE-HI condensed catalog can be obtained from leading distributors and rubber manufacturers everywhere or by writing direct to Hose Accessories Co., 17th and Lehigh, Philadelphia 32, Pa. Ask for Catalog No. 149.

Worn Crankshafts Reclaimed with Metallizing

Metallizing saves money by reclaiming crankshafts. The March issue of the *Metco News* is full of facts, telling how many metallizing users save money and time by rebuilding worn mains and throws on crankshafts.

To the owners of automotive and industrial engines, gas or Diesel, air and ammonia compressors, stamping, punch press and textile cranks and shafts, metallizing offers a number of advantages over the old method of grinding worn mains and throws and refitting with undersize bearings. Metallizing also offers improved performance and longer service life due to two important characteristics of sprayed metal: (1) Superior lubrication, due to the oil-holding pores in the surface. (2) Greater particle hardness in the metallized coating than in original metal of the same composition.

One metallizing user who has metallized bus engine crankshafts for over ten years reports that many shafts have had all eight throws metallized and have operated well over 100,000 miles. Rebuilding one of these crankshaft throws to original size, 1.987 in. requires 2¼ hr. labor and a total cost of $3.14. Another shop reports metallizing over 7000 crankshafts in three years. A plant, operating 128 nail forming-machines—each with a crankshaft that takes continuous punishment, reported savings over a year's time of 320 man-hours and $2460 in cash.

Other applications are also suggested such as armature shafts, bearing fits, journals, piston rods, rolls and spindles. Avoid costly shutdowns. Write for your copy of *Metco News*, Vol. 4, No. 7. Metallizing Engineering Co., Inc., 38-14 30th St., Long Island City 1, N. Y.

Thought Starters

To present interesting case histories and ideas on how to use arc welding most effectively in cutting factory operating costs and production costs, The Lincoln Electric Co., Cleveland 1, Ohio, is publishing an 8-page rotogravure news sheet. *It's Welding Time* is issued regularly and is sent free to factory personnel interested in cutting the costs for which they are responsible.

It's Welding Time is edited and prepared not to present detailed explanations of how to do specific jobs, but is intended rather to be a thought starter for the cost conscious plant superintendent, plant engineer, master mechanic, methods engineer and maintenance engineer. The issue now being distributed contains over 50 photographs and drawings showing how plants in all parts of the country are using arc welding. Illustrated are: *maintenance ideas*—how machinery is kept operating efficiently; *design ideas*—how better products are made at less cost through welded design; *building ideas*—how welding permits easy erection and maintenance of plant capacity; *equipment ideas*—how special plant equipment is made for special production jobs.

It's Welding Time is sent free of charge to those interested by writing to The Lincoln Electric Co., Cleveland 1, Ohio, on company letterhead.

The Economies of Hardfacing

The availability of a helpful, new reprint "The Economies of Hardfacing" has been announced by Air Reduction Sales Co. Written by J. J. Barry and Albert Muller, this reprint originally appeared in article form in THE WELDING JOURNAL. The 8-page reprint, profusely illustrated with 14 photographs, reviews the advantages of hardfacing and offers an analysis of the problems leading to the correct selection of the proper hardfacing rods. Design and cost figures are offered, plus a selected bibliography.

Copies may be obtained without charge by writing the Airco office nearest you, or Air Reduction Sales Co., 60 E. 42nd St., New York 17, N. Y.

Design for Welding

Design for Welding in Mechanical Engineering, by F. Koenigsberger, published by Longmans, Green and Co., Inc., 55 Fifth Ave., New York 3, N. Y., 210 pages. Price $4.50. This book is an attempt to coordinate theory and research results with the experience gained in the actual design and manufacture of welded structures as used in mechanical engineering.

An attempt has been made to stress the theoretical and practical factors which might assist the designer of welded steel construction.

Great weight is given to the use of a correct drawing practice in connection with designs for fabricated welded construction. The author is of the opinion that the drawing-office work is the true basis for any production process in general, and for the operations in the welding shop in particular.

A list of Chapters are: (1) "The Materials Used for Fabricated Welded Steel Structures," (2) "The Welded Joints," (3) "General Design Principles for Welded Construction," (4) "Detail Design of Typical Part-Assemblies Used in Fabricated Welded Construction," (5) "Typical Welded Structures" and (6) "Drawing Practice to Ensure Efficient Fabrication by Welding."

Nonferrous Metals

The Lincoln Electric Co., Cleveland 1, Ohio, has issued a four-page technical leaflet giving information on electrodes and procedures for welding aluminum, bronze, brass and copper.

Studs

Twenty-four picture paragraphs covering as many popular uses of the Nelson studwelding gun are included in a new 8-page catalog of manufacturing and construction applications.

Typical production units and a wide range of special studs are shown along with a concise description of the Nelson method of fastening to metal. Nelson Studwelding Division, Morton Gregory Corp., Lorain, Ohio.

Measuring Thickness of Metals

The Sperry Reflectogage, a portable, ultrasonic instrument for measuring thickness of materials from one side only, is described in a new publication, *Bulletin 3700*, announced by Sperry Products, Inc., Danbury, Conn.

The new bulletin describes the theory and general application of the instrument to nondestructive measurements of plate and sheet stock, tanks, boilers, pipe, extruded shapes, hollow propellers and other formed parts and assemblies of various metals and plastics up to 4 in. in thickness. Interpretation of the visual ultrasonic indications is also described and illustrated.

Other uses of the Reflectogage described in the bulletin are tests for lack of bond, lamination and internal defects in sheet stock.

Fundamentals of Soft Soldering

Fundamentals of Soft Soldering, by Charles Yerkow, combines the best features of school and trade practice in the teaching of soldering. Experience in a commercial shop as well as in training beginners caused the author to analyze the basic "factors" of a good soldered joint.

These he has set down as the four factors every student must observe. No attempt is made to show examples of every type of joint, but the simple examples here explained and illustrated may be applied to all general soldering problems.

The photographs take up procedures step by step. They are large, clear and definite.

This is a book every school shop instructor or home craftsman will appreciate, because it eliminates the difficulties most beginners have with making a good soldered joint.

Published by The Manual Arts Press, Peoria 3, Ill. Price $2.25.

WELDING CONNECTORS

Saze System Welded Connection Units for welded assembly

Saze Units place in position and securely hold together structural parts to be welded.

As used in many welded structures they *eliminate all hole punching* producing an economical, rigid, safe and quickly erected structural frame.

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NEW PRODUCTS

Stainless Electrode

The Champion Rivet Co., Welding Division, announces their new 316-CF Stainless Steel Electrode. This electrode has been developed to weld Type 316-ELC Stainless Steel which is now produced in sheets, bars and plates. The unusual feature of this analysis is that the carbon content is the *lowest that has ever been produced* in Stainless Steel—0.03% max. With this small amount of carbon in the parent metal and electrodes, it is possible to practically eliminate intergranular corrosion in the zone adjacent to the weld and in the weld deposit because carbide precipitation is prevented.

Properties of weld metal are: carbon, 0.03% max.; chrome, 18.00%; nickel, 13.00% and molybdenum, 2.25%.

Physical properties as-welded: tensile strength, 85,000 to 95,000 psi.; elongation in 2 in., 40 to 50%.

Midget Single-Stage Regulators

Seven, new, small single-stage regulators, to be known as the Midget 7400 series, have been announced by Victor Equipment Co., welding apparatus manufacturer, 844 Folsom St., San Francisco 7, Calif.

These new regulators are designed especially for users of small acetylene cylinders where hourly gas consumption and space is limited. They weigh only 1 lb., 12 oz. each, and are simply constructed for easy maintenance. Any part may be replaced and the entire regulator reassembled in 15 min. or less.

The series includes:

7401 Acetylene regulator for shops with occasional welding and brazing. Big enough for all cutting jobs; handles welding nozzles up to size 8.

7403 Liquefied-petroleum gas regulator for medium capacity brazing and cutting with propane or butane.

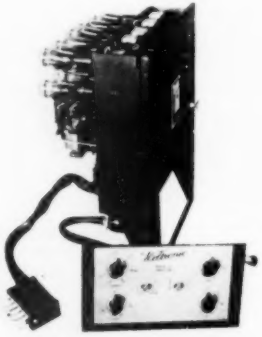
7404 Oxygen line regulator for sit-down production line work with inlet pressures of approximately 200 psi.

Leak Detecto Brush

A new tool has been developed for detecting leaks in gas lines. The tool involves a special brush with a liquid solution especially developed for this purpose. Price $3.00, postage prepaid; Gas Appliance Stores, Inc., 706 Harden St., Columbia, S. C.

Sequence Weld Timer, NEMA 3B and 5B

This latest model relay firing timer employs standard octal base thyratron tubes and is designed for interchangeable front or side mount of timer dials when employed in a standard control combination.



Timer panels incorporate the usual Weltronic "Plug-in, Swing-out" construction. Opening of front panel provides easy access to resistors, capacitors and wiring. Independently adjustable time periods. Industrial heavy-duty relays. Precharged timing capacitors insure accurate timing. Universal power supply. Also available for 25-cycle operation. Cabinet size: 18 in. wide, 16 3/4 in. high, and 12 in. deep.

When the timer is employed in a standard NEMA combination, the panel holding the timer dials and toggle switches may be mounted on the front (for wall mounting) or on the side (for side of welder mounting) by a simple quick change in mounting screws.

Obtain complete details in *Bulletin No. 16*, Weltronic Co., 19518 West Eight Mile Road, Detroit 19, Mich.

Air Torch

Weldit, Inc., announces the introduction of a new series of torches designed to use atmospheric air and either propane or acetylene, available everywhere in small, economical tanks.

These torches will find use among plumbers, electricians, painters, tinners and roofers, and in automobile, farm and home repair shops. They are suited for use on radiator and battery repair, body work, for silver brazing, refrigerator or condenser repair or similar work where compressed air and gas is not available. They are ideal for paint removal from wood or metals or for fine soldering and heating jobs.

Torch C-48 (shown) has full Weldimatic trigger control, adjustable pilot light and needle valve adjustment.

For information on the variety of burner tips available and prices, write Weldit, Inc., 990 Oakman Blvd., Detroit 6, Mich.

Regulator

This new cutting and welding regulator is constructed of aluminum with stainless steel wearing parts, with an exclusive practical guard protecting the fragile pressure gages. Designed with a minimum number of parts, only one socket wrench is necessary to service the regulator. Unique design of working parts enables replacement of nozzle, seat, pin and filter as a unit in the record-breaking time of two minutes. The regulator is constructed to withstand shock, such as being dropped, without damage to the pressure gages, and meets a universal need in the welding field for protected regulators and results in low maintenance costs. Oxo Welding Equipment Co., 1235 W. 95th Street, Chicago 43, Illinois.

New Type "Cold" Solder

New type body solders made from powdered aluminum appear destined to replace the older type solders which had to be melted and "flowed in" to dents and other damaged areas of automobile bodies. The new solders require no heat, and thus avoid damaging adjacent painted surfaces. Several successive applications can be employed to build up thicknesses as much as 1 in.

Reynolds Metals Co. has actively aided the development of these materials and is now supplying large quantities of aluminum powder to concerns making the new type solders which are now available to the public and specialty trades through paint jobbers, large paint stores, automotive finishing supply houses and similar outlets.

These "cold" solders are doughlike—about the consistency of plastic wood. When applied by spatula or wiper, the solvent evaporates and the metal mass soon hardens sufficiently to be filed or sanded. It adheres strongly to a properly cleaned surface. When sanded smooth, it provides an excellent base for paint, enamel or lacquer coatings.

"Blinker" Helmet

This new welding helmet with its movable "Blinker" lens supplies a very definite answer to today's "both hands needed" modern welding methods, such as heliarc, and for fit-up of work, tacking and all-round precision welding.

Its movable lens principle permits the welder to lower and raise the filter lens (without raising his helmet) by a simple downward or upward movement of his chin against a pivoted chin strap. This leaves both hands free at all times, whether welding or not. In some cases it may make a helper unnecessary. When the welder does not have to nod his head to get his helmet in place, the work does not shift out of position just prior to striking the arc.

With this "Blinker" helmet, welders may work safely in confined spaces i.e., tanks, sections of ship's hulls, locomotive front ends, fire boxes, boilers, etc. It also permits slag chipping with no possibility of hot slag burning the face, or injuring the eyes. The helmet also gives ample protection from side flashes when welding with a group.

Constructed of best grade vulcanized fiber, this helmet has been thoroughly tested under humid, dry and other atmospheric conditions. Its protective lens meets Federal Specifications in all shades desired. Clear cover glass inside and out gives full protection. Head gear and chin rest are fully adjustable for ease and comfort. Priced at $11.95 each.

Completely illustrated descriptive literature available. Write: Welders' Products, Dept. 159, 141 W. Jackson Blvd., Chicago 4, Ill.

A.-C. Arc Welders

A new line of a.-c. arc welders, featuring increased welding range and stepless precision current control, has been announced by General Electric's Welding Divisions.

The new welders are available in 200-, 300-, 400- and 500-amp. models for indoor manual welding; 750- and 1000-amp. models for machine and submerged melt welding, and a special 200-amp. model for light-duty, job-shop welding. The 300-, 400- and 500-amp. models are offered also in weather-resistant enclosures with Idlematic control for both indoor and outdoor operation.

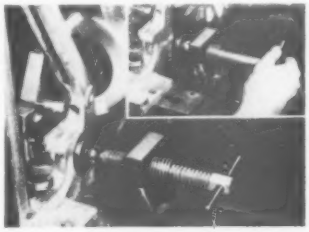
Dual current ranges and increased adjustment overtravel on the new machines provide extra low-current range with high maximum short-time output. They are designed with stepless current control, operated by a bearing-mounted current-adjustment crank which enables the operator to make precision settings throughout the current range.

The new welders have an open-circuit voltage of 75 v., providing good welding performance through added arc stability. Idlematic controls on the weather-resistant models automatically reduce the open-circuit voltage on the electrode to about 30 v., but when the arc is struck the advantage of 75-v. open-circuit voltage is retained.

Increased strength and protection for the welders are provided by the newly designed steel housings. Built-in power factor correction helps to keep down power consumption, thus lowering operating cost. Cool operation is attained through the use of up-draft, fan-assisted ventilation.

Quick-Action Work-Holding Units

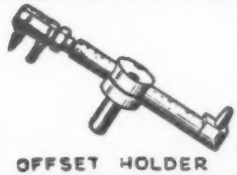
Mechanics Engineering Co., Inc., Jackson, Mich., announces a redesigned line of work-holding units of a positive quick-acting type, under the brand name of Bar-Lok for use in jigs and fixtures, and for positioning in machining, welding, brazing, plastics and woodworking and a wide range of assembly jobs. With these units, the time required for clamping and releasing the work is reduced to a minimum by eliminating the usual screw action.



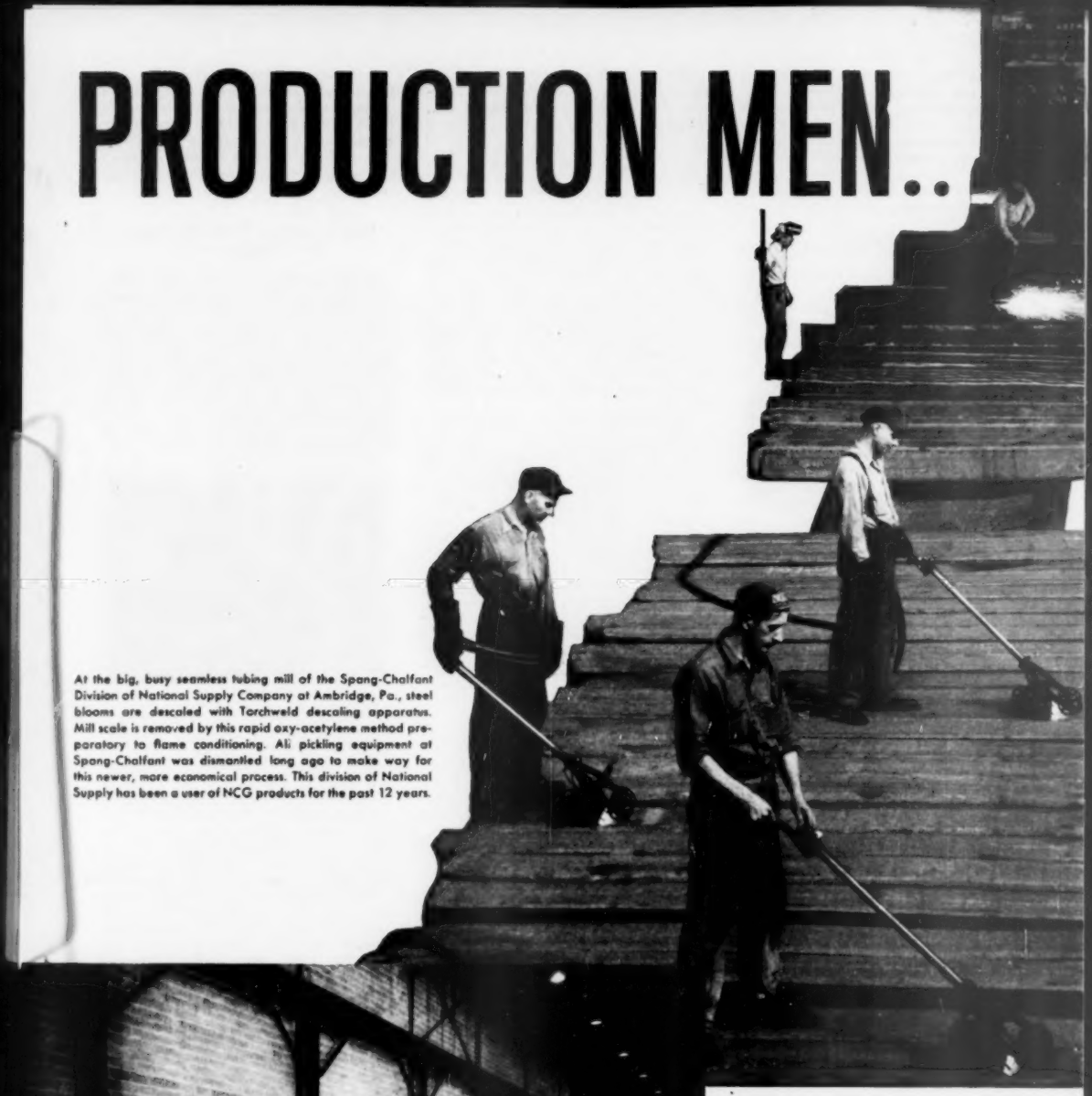
This is accomplished through the use of a radially grooved square pressure bar which slides freely through a threaded collar when turned toward the left (counter-clockwise) against a stop. In this position, the foot of the bar is placed against the work instantly, from a full-open position. The bar is then turned toward the right (clockwise), which brings it into engagement with the threaded collar, thus applying screw pressure against the work.

To release the work, the bar is turned toward the left, releasing the screw pressure and re-entering the free-sliding position, in which it is instantly drawn away from the work. With products of intricate shape or having deep cavities, the time saved in applying and releasing the pressure is considerable.

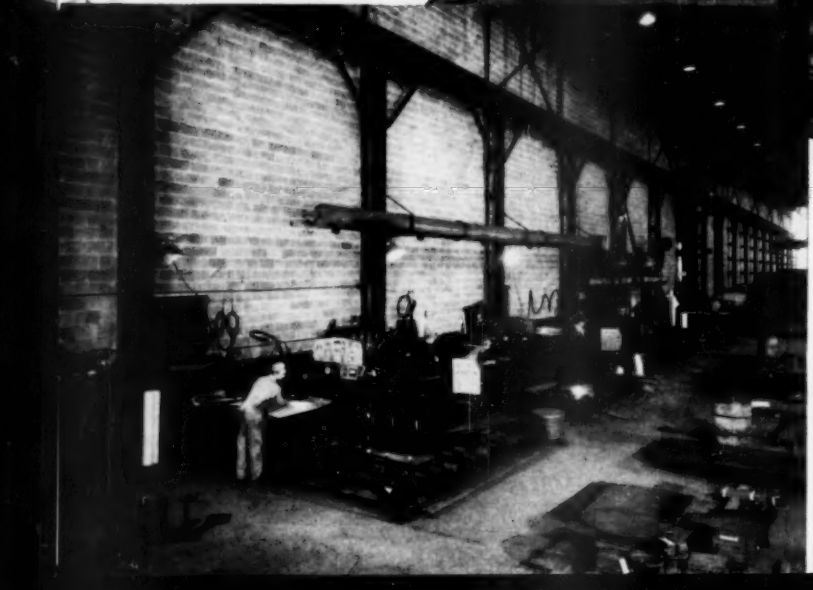
The Bar-Lok units are available in three series to meet variations in pressure requirements and to provide a range of lengths up to 12 in. There is a choice of tee or swivel handles, and of square, round or flexible feet. All parts are made of hardened steel, cadmium-plated, for long life in high-production service and resistance to corrosion.



PRODUCTION MEN..



At the big, busy seamless tubing mill of the Spang-Chalfant Division of National Supply Company at Ambridge, Pa., steel blooms are descaled with Torchweld descaling apparatus. Mill scale is removed by this rapid oxy-acetylene method preparatory to flame conditioning. All pickling equipment at Spang-Chalfant was dismantled long ago to make way for this newer, more economical process. This division of National Supply has been a user of NCG products for the past 12 years.



A battery of four NCG "RS" Cutting Machines are used to speed production at the R. C. Mahon Co., Detroit, Mich., steel fabricators and manufacturers of a wide variety of industrial and building products. Mahon has standardized on NCG's Torchweld No. 75 hand cutting torches, and relies exclusively upon NCG gases. In the case of machine cutting, gases are abundantly provided from a portable bank, seen at left in the picture.

. . . . . NEVER GUESS

Only TORCHWELD performance could win such widespread respect and preference

For many years Torchweld regulators and Bantam welding torches have been used in the welding and finishing of bodies at the Toledo plant of Willys-Overland Motors, Inc., makers of the famous Universal Jeep, Jeep Station Wagon, Jeep Truck and the "Jeepster." The picture shows Torchweld Bantam Torches (formerly known as "Aircrafter" torches) putting final touches on bodies for the Jeepster, Willys-Overland's latest innovation in the American motor car field.

Where gas consumption is measured in millions of cubic feet and production in thousands of tons, apparatus can't be *almost* right—it's got to be *just* right! And it *is* right when it's performance-proved Torchweld apparatus for cutting, descaling, scarfing, welding or any of the dozens of other chores the oxy-acetylene flame does best. . . . Built into *every* Torchweld tool are quality, precision and the experience of 30 years. . . . Give Torchweld a tryout in your operation and discover for yourself new efficiency and *economy*.

NCG

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Executive Offices:

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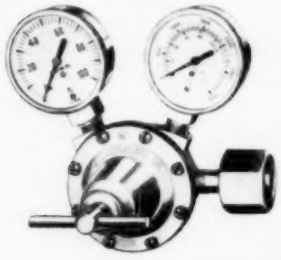
For simple clamping, a line of medium-duty Bar-Lok pressure units in especially adapted C-clamp frames is offered and, for application to jigs and fixtures, an internal-threaded adapter which may be bolted, welded or brazed into position.

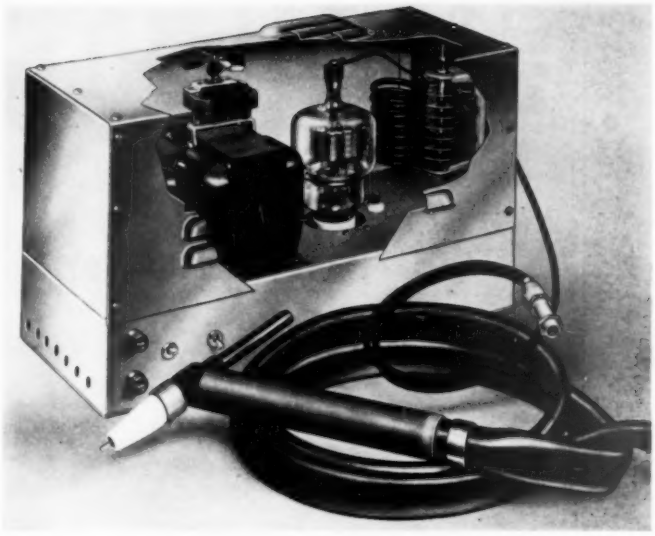
Regulators

New single-stage welding regulators, for oxygen and acetylene, which equal the performance of most two-stage regulators are now in production by the C. A. Norgren Co., Denver 9, Colo.



They are the yoke type for maximum safety, assure positive delivery of oxygen and acetylene at correct pressures without creep and hold the secondary pressure while tank pressure falls. An exclusive ball-pivoting lower spring rest assures permanently friction-free operation. Another exclusive Norgren construction feature is the O-rings between yoke and diaphragm and between body and bonnet to seal and cushion the diaphragm for superior performance and easy maintenance. Special design guides the jet accurately to disk so it always seats at exactly the same locations for a perfect seat.

These Norgren welding regulators are listed by Underwriters' Laboratories, Inc. Each model is complete with primary and secondary pressure gages and standard tank connection. They are easily and completely dismantled, requiring only a screw driver and crescent wrench, without removal from the cylinder. Each unit is performance tested before shipment. Complete information by writing the manufacturer: C. A. Norgren Co., 222 Santa Fe Drive, Denver 9, Colo.



New G-R Inert-Gas Arc Welders Receive Federal Communications Commission Approval

Solution to the problem of radio interference from welders using high-frequency pilot circuits is indicated by the granting of Federal Communications Commission approval to the new "IGT" model G-R welders for inert-gas arc welding, just announced by the Glenn-Roberts Co., Inc., of Indianapolis.

The G-R "IGT" models utilize a tube-type oscillator with extremely stable frequency characteristics, used with a specially modified torch providing maximum transfer of radio-frequency energy. Spurious and harmonic radiation is reduced to levels permitted by the F.C.C. The unit remains on frequency regardless of working conditions, changes in humidity or temperature. The oscillator is a full-wave, self-rectifying type, using but a single tube. Designed as a compact, self-contained unit, the oscillator has extremely few component parts and is ruggedly constructed for long-service life. Patents are pending on the new unit.

In addition to FCC approval, the new "IGT" model G-R welders offer several other advantages. Greater arc stability is provided by the continuous, uninterrupted flow of high frequency at 27,120,000 cycles per second all during the welding cycle. "Missed" cycles common to spark-gap oscillators are eliminated, and the need for frequent gap adjustment is avoided.

Safety is assured by the fact that the entire high-frequency circuit operates at ground potential; maximum voltage at the torch is the welding voltage (approximately 20 v.). No "feedback" of high frequency into the welding machine occurs, protecting the machine against insulation breakdowns.

"Touch start" control, incorporated in the oscillator design, provides automatic "cold" starting; when the electrode contacts the workpiece, a 6-v. control circuit is energized which turns on the high frequency. When—and only when—the high-frequency arc is drawn, welding

WANTED

Up to six 500, 1000 or 1500 ampere Rectifiers 440 volt to 6 volt. Must be in first rate condition and low priced.

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Wall Wire Products Co.
Plymouth, Michigan

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General Electric tungsten electrodes, for Inert-Arc and atomic-hydrogen welding, assure you quality of content, plus precision finish. They are now available for manual and automatic welding in diameters ranging from .040 to ½ inch and in lengths of from 3 to 24 inches as standard. Random lengths up to 60 inches furnished on request.

For more detailed information, see your local G-E Arc-welding Distributor, or fill out the coupon and mail it today. We will send you a copy of the easy-reference G-E Arc-welding Accessory Catalog.

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current automatically comes on. Because no welding current flows while the electrode is in contact with the work, sticking of electrodes is avoided. Both high frequency and welding circuits automatically shut off when the arc is broken. Manual controls on the welder are extremely simple, consisting only of the current regulator handwheel and an on-off switch for the oscillator. Automatic gas and water controls are optional at nominal cost.

Use of an "arc balancing" circuit in the "IGT" welders greatly improves both welding characteristics and power factor, resulting in lower current input. Dual-range output provides extremely wide working range.

New G-R "IGT" models are being manufactured in NEMA ratings of 150, 200, 300, 400, 500 and 750 amp. The FCC-approved G-R tube oscillator and modified torch are also available for use with other a.-c. and d.-c. welders for inert-gas arc welding. Approval numbers are ME-472 and ME-474.

Complete information on the G-R "IGT" welders, and the G-R tube oscillator, may be obtained by writing Glenn-Roberts Co., Inc., 2107 Adams St., Indianapolis 18, Ind.

Electrode Solves Problems in Welding Cracked Motor Blocks

Freezing weather always brings the industry problems of cracked automotive cylinder blocks, heads and exhaust parts. Such damage cannot easily be repaired by replacement because of inaccessibility, prohibitive cost and time-consuming dismantling processes.

Motor block welding definitely requires welders and preheated furnaces—a job the garage welder dares not undertake. But with New Eutectrode 24/29, the "cold" arc-welding electrode for cast iron, adaptable to a.-c.- or d.-c.-welding machines, an immediate solution to the problem is at hand, since any metalworker can easily perform the job right on the spot! This low-heat welding electrode may be used without preheating the base metal, insuring the job with no distortion or warping. The motor, without being dismantled, may be welded in its immediate position using lowest amperages and lowest voltages! Eutectrode 24/29 is manufactured by Eutectic Welding Alloys Corp., New York, and is available in sizes $^3/_{32}$, $^1/_8$, $^5/_{32}$, $^3/_{16}$ and now the new $^1/_4$ in. for big cast-iron castings.

Finished weld is leakproof, strong and thoroughly machinable—a job the average welder can make with a regular machine using very lowest heat. The accompanying photograph is a typical repair job on a motor block, done right in position using Eutectrode 24/29. Each bead was peened to relieve stresses. This entire job used a minimum of time and material, and savings are even greater when replacements costs are considered.

Additional information on Eutectrode 24/29 and other low-heat welding alloys for all metals may be obtained by writing to Eutectic Welding Alloys Corp., 40 Worth St., New York 13, N. Y.

Cup-Type Goggles

A new cup-type goggle claimed to be one of the safest and most comfortable goggles of its kind has been announced by the Chicago Eye Shield Co.

The goggle features newly developed molded thermoplastic cups. This material gives the strength and durability of commonly used substances, with 30 to 40% lighter weight. Cups are engineered to fit both left- and right-eye areas snugly yet gently, and have broad contact surfaces which eliminate "pressure spots."

Another feature of this newly designed Cesco goggle is the molded rubber Comfort-King headband, which provides added comfort to wearers. This headband holds

the goggle firmly with 30% less tension. It will not kink, curl or twist, and has no buckles or sharp edges. Patented slip-disk size adjustment is quick and simple.

This new Cesco cup-type goggle is available in various styles for chipping and welding protection. For complete information, write Chicago Eye Shield Co., 2300 Warren Blvd., Chicago 12, Ill.

Electrode Holder

The patented* improvement that distinguishes this new welding electrode holder is the sharp angle design of the jaws. The angle shape of the jaws allows the operator to use the rod down to the shortest possible stub, with an estimated saving of 20% on electrodes. The angle jaw has the additional advantage of affording the operator an unobstructed view of the arc at all times and in all welding positions.

Instant reloading with one hand is made possible by the trigger-lever that opens the self-spring jaws. Five gripping channels in the jaws give the operator a choice of angles in placing the rod, eliminating the necessity of bending electrodes to reach into deep pockets.

Other key features: light (16-oz.) weight; fully insulated with unbreakable plastic over copper jaws that take from $^1/_{16}$ to $^1/_4$-in. electrodes; simple cable connection that takes various diameters without adjustment; no separate springs, collets or other small parts.

The Ben-Nek Holder, Inc., plant and offices are in East Haven, Conn.

*U. S. Patent No. 2,377,203.

High-Frequency Welder

Approval for the Sureweld Gasarc high-frequency welder made by the National Cylinder Gas Co., Chicago, was granted by the Federal Communications Commission.

The FCC, in giving NCG the green light to manufacture high-frequency, inert-gas arc welders, acknowledged that characteristics of the new NCG oscillator and specially designed torch will keep the unit on its assigned frequency at all times, and eliminates the problem of communications interference.

NCG's engineering organization has designed a tube-type oscillator with extremely stable frequency characteristics. This is used with a specially modified torch assembly which provides maximum transfer of high-frequency energy.

Regardless of working or weather conditions, the Gasarc welder remains on the assigned frequency of 27,120 kc. It causes no communications interference by either fundamental or harmonic radiation.

The Gasarc oscillator is a full-wave, self-rectifying type using a single tube. It is a self-contained unit with extremely few component parts.

The new Gasarc torch, also approved by the FCC, is "tuned" to preserve freedom from interference while transferring high-frequency energy from the oscillator to the welding arc. The torch assembly uses coaxial cable for the high-frequency transmission.

In addition to eliminating interference with television and radio reception, the NCG Sureweld Gasarc unit offers several improvements in welding performance. Greater arc stability is provided by the uninterrupted flow of 27,120 kc. per second all during the welding cycle. "Missed" cycles, common to spark gap oscillators are eliminated, and the need for frequent gap adjustments is avoided.

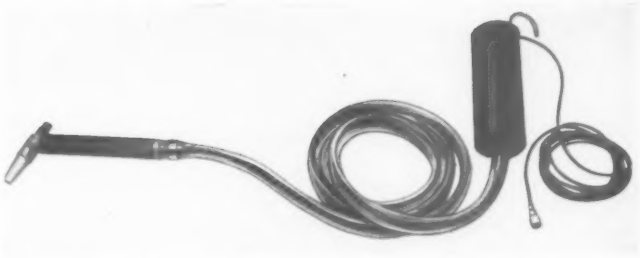
An entirely new arc-starting procedure, called by National Cylinder Gas Co. "touch start control," provides automatic "cold" starting. The electrode is contacted with the work at the point where the weld is to begin. The welding operator can locate the starting point of the weld accurately because he can make this contact with his helmet raised.

Touching the electrode to the work energizes a control circuit which turns on the high-frequency current. Then, after lowering his helmet, the operator withdraws the electrode. This automatically turns on the welding current and establishes the arc. Since no welding current will flow while the electrode is in contact with the work, sticking of electrodes is avoided. Both the high-frequency and welding currents are shut off automatically when the arc is broken. To restart the arc, the same procedure is followed.

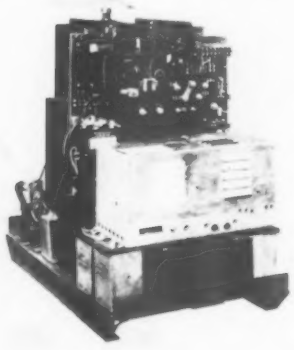
A special balancing circuit used on the inert-gas arc not only improves welding characteristics, but results in a higher power factor which reduces input current substantially.

The new oscillator unit will be an integral part of NCG's Sureweld Gasarc inert arc welders, to be made in six models ranging from 150 to 750 amp. in capacity. The oscillator unit and "tuned" torch also will be available for use with other welders.

Complete information on the newly approved equipment may be obtained from the National Cylinder Gas Co., 840 N. Michigan Ave., Chicago 11, Ill.



The Gasarc torch utilizes coaxial cable and a built-in tuning device to maintain freedom from interference while carrying high frequency energy at 27,-120,000 cycles per second from the oscillator to the welding arc. Flexible plastic cable provides passage for welding current, inert gas, high frequency current and a circulating water supply for cooling the electrode holder



The self-contained Gasarc oscillator unit shown above as part of the Sureweld Gasarc welder is available separately for use with other welding machines

Acetylene Cylinders

Details of a new line of Acetylene cylinders they are making have been announced by Aetna Cylinders, Inc., 714 Fisher Bldg., Detroit 2, Mich.

These cylinders have a monolithic filler which permits not only faster filling but more gas capacity. This combined with their lighter weight enables the manufacturer of compressed acetylene to effect considerable savings—both in labor and trucking and shipping costs.

Aetna cylinders are available at present in 4 sizes —39 x 12 in., 30 x 10 in., 30 x 18 in. and 24 x 6 in. Bottom rings come as standard equipment on all sizes.

Aetna cylinders are equipped with a top quality valve—with either Prest-O-Lite type or commercial fittings. Caps can be supplied with cylinders when required.

All Aetna cylinders have 5 safety plugs and are manufactured in strict conformance to I.C.C. specifications.

Welders' Protective Clothing

A new development in safety clothing for welders is announced by Lester L. Brossard Co., 540 N. Michigan Ave., Chicago 11, Ill. In place of leather, this company is using *Asbeston*, a remarkable new burnproof and heat-resistant no lint fabric, developed to meet the need for a durable, washable and comfortable lightweight protective garment that can be worn for hours without discomfort to the worker. This new fabric has been tested,

approved and used by the U. S. Navy for fire-fighter suits. Washing or dry-cleaning does not harm this fabric, nor reduce its flameproof qualities. Aprons, arm sleeves, bibs and jackets are now available in this new material.

Hydraulic Press Becomes Welder's Aide

Recently becoming very popular in the welding field, is the 50-ton hydraulic press manufactured by Bee-Line Co., Davenport, Iowa. This press has proved itself to be an outstanding part of welder's shop equipment. A movable ram is supported

50 Ton Hydraulic Press

on rollers and can be positioned at any point on the track. Pressure is quickly applied and released. Spring action removes the ram clear of the work for better accessibility. Welders are constantly reporting new uses of this press, making difficult welding jobs easier.

Welding Kit

A handy compact welding kit containing low-temperature alloys and fluxes for any gas welding job is now available from All-State Welding Alloys Co., Inc., 273 Ferris Ave., White Plains, N. Y. The complete kit comes in a metal box and is known as the All-State Doc Alloys Kit which "has everything to weld anything."

This kit, which is "field designed," meets a long-felt need for welder, distributor and manufacturer alike. It is the handiest kit yet designed to become standard equipment with every gas welding outfit kept on contract jobs, on ships, on farms and for field repair of every kind as well as for the maintenance welders in plants, factories, quarries, mines, foundries, etc. To the welder it gives in a relatively small metal box ($2 \times 4\frac{1}{2} \times 20\frac{1}{2}$ in.) an ample supply of silver solder and 10 other different kinds of low-temperature gas welding rods, a low-temperature galvanizing powder and 8 fluxes. The rods are individually color marked and in labeled pockets in a leatherette roll; flux jars have individual labels; a booklet of complete instructions is included; and the cover of the box contains a convenient chart of the contents with practical working directions.

Welding Kit

"Water-Saver" Valve for Controlling Coolant

Recognizing that coolants used on welders and machine tools frequently become an important cost factor, a "water-saver" valve has been introduced by Ross Operating Valve Co., Detroit 3, Mich.

"Water-Saver" Valve

The new control is a straight-way or shut-off valve normally open or closed to the water supply. It allows the coolant to run when needed but automatically turns it off between required periods. A time-delay adjustment is set for maintaining the coolant flow for a period from 0 to $2\frac{1}{4}$ min. after the machine cycle.

Operation of the valve is purely automatic requiring no electrical or mechanical motivation. It is generally activated by the same power which moves the machine cylinder. A "Pressure-Booster" modification is available for use when the cylinder pressure is less than the water pressure.

Hydraulic Lift Truck

Large reels are easily handled with a special hydraulic lift truck designed by Lyon-Raymond Engineers.

The reel carrier is built on the pattern of a single face pallet truck. Two base forks are provided with a center opening wide enough to straddle the reel to be lifted. Two uprights, welded to the base forks, have hooks which slip under the ends of a shaft passing through the reel hub.

Hydraulic Lift Truck

Elevating the truck 5 in. by means of the self-contained hydraulic pumping unit lifts the reel so that it can be easily transported. The operator has control of the load at all times since it is raised by pumping the truck handle and lowered by means of the convenient finger-tip release lever.

The truck shown has a capacity of 1000 lb. It is furnished with either rubber-tired or metal wheels. Fork openings and the height of pickup hooks can be furnished to meet a wide range of reel sizes because each truck is built as a special unit.

Inquiries should be addressed to the Lyon-Raymond Corp., 1950 Madison St., Greene, N. Y.

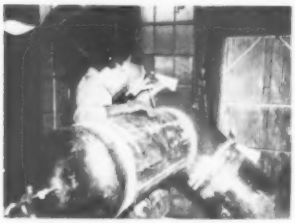
ANNUAL MEETING
AMERICAN WELDING SOCIETY
WEEK OF OCTOBER 16
CLEVELAND HOTEL
CLEVELAND, OHIO

In conjunction with National Metals Congress and Exposition, Cleveland Public Auditorium.

TUBE-TURN

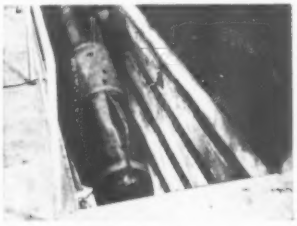
WELDING FITTINGS AND FLANGES

18-inch standard weight Tube-Turn welding tee and pipe laid out preparatory to assembly for hydrostatic pressure test.



Welder completing last bead in assembly. Fitting and pipe now form homogeneous, leakproof unit.

Assembly is hung in pit, massively lined with concrete. During test top grating is closed and held down by a barricade of sandbags.



Final result after hydrostatic pressure test. The straight pipe burst first, and the tee is undamaged.

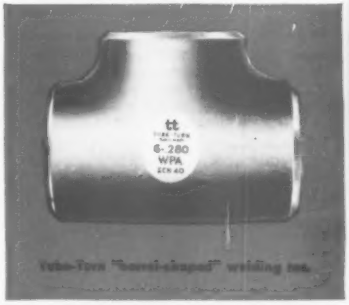
Strength through Design in Tube-Turn welding fittings

The pipe burst first!

Take an 18-inch standard weight welding tee. Take three corresponding lengths of pipe. Weld tee and pipe together. Cap the ends. Lower the assembly into a pit. Then apply hydrostatic pressure—much more than the assembly is supposed to take!

Something has to give! According to the accepted beliefs it should be the tee. But not in the case of the test pictured here. The Tube-Turn "barrel-shaped" tee was used—and the pipe burst, well before the tee was affected! Throughout numerous tests, this new type of tee has withstood at least 25 per cent more pressure than required by the formula given in ASA B16.9.

The superior strength of the tee was achieved without running up extra weight and cost, by carefully planned improvements in shape (based on the sphere, nature's strongest form for internal pressure), and by a carefully engineered distribution of metal.



Tube-Turn "barrel-shaped" welding tee.

This is a typical example of *strength through design* in Tube-Turn welding fittings, and another good reason why leading piping engineers specify Tube-Turn equipped, welded piping.

TUBE TURNS, INC.

222 East Broadway, Dept. G, Louisville 1, Kentucky

District Offices at New York, Philadelphia, Pittsburgh, Chicago, Houston, Tulsa, San Francisco, Los Angeles

abstracts of
CURRENT WELDING PATENTS

prepared by V. L. Oldham

Printed copies of patents may be obtained for 25c from the Commissioner of Patents, Washington 10, D. C.

2,462,199—Method of Resistance Welding Using Partially Sheared-Out Projections—Joseph W. Kehoe, Wilkinsburg, and Joseph B. Dym, Pittsburgh, Pa., assignors to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

This patent relates to a projection welding method wherein two metallic members are secured together with one metallic member having a projection formed thereon by partially shearing a portion of metal therefrom by a punching operation. A current conducting electrode is positioned on the one member at the rear of the projection formed thereon, after which electric current is passed through such one member, and the other member to produce sufficient heat to fuse the partially sheared portion out of one member to the other member.

2,462,458—Spot-Welding Apparatus—Marshall Beymer, Chicago, Ill., assignor of one-half to Henry L. Sweitz, Chicago, Ill.

Beymer's patent is on a portable spot-welding apparatus wherein an elongate body including a transformer is provided. A fixed upper electrode is supported on the body and a movable lower electrode is also carried by the body. A clamping handle extends from the body at the upper portion thereof and is pivotally carried thereby and connected to the lower electrode for controlling the position of same.

2,462,463—Electric Arc-Cutting Electrode—Robert Henry Farmer Boot, London, England, assignor to Under Water Welders & Repairers Limited, London, England, a British company.

This patent covers an electrode for underwater arc cutting and the electrode includes a carbon body with a metal casing surrounding same. An insulating cover is over the metal casing which has a passage provided therein between the carbon and the casing for conveying oxygen from end to end of the electrode.

2,462,561—Welding Apparatus—Siebert Schneider, Oakwood, Ohio, assignor to General Motors Corp., Dayton, Ohio, a corporation of Delaware.

This patent covers a specialized welding machine wherein a single column of electrodes is stationed in spaced relation to one another and arranged in a form of predetermined configuration. A plurality of bus bar contact members are provided at predetermined positions and the column of electrodes is moved through a path to contact the bus bars and close welding circuits at desired times so that the individual electrodes in the column of electrodes can make a series of welds.

2,463,075—Torch Holder for Cutting Openings—Roy O. Young, Bell, Calif.

This patent is upon a special type of torch holder apparatus.

2,463,096—Welding Electrode—Francis E. Garriott, West Allis, Wis., assignor to Ampco Metal, Inc., Milwaukee, Wis., a corporation of Wisconsin.

This patent is on a bronze electrode for arc welding and includes a bronze core rod having a covering comprising fluoride slag producing materials and a silicate binder. Iron and potassium are present in the covering in the form of iron and iron oxide and feldspar and potassium silicate, respectively.

2,463,129—Machine for Welding Together Pieces of Metal Wire—Jan van der Windt, Eindhoven, Netherlands, assignor to Hartford National Bank and Trust Co., Hartford, Conn., as trustee.

This patent is on a special machine for forming a weld between one end of a first wire and one end of a second wire and also forming a weld between the other end of the first wire and one end of a third wire.

2,463,158—Apparatus for Brazing Articles—Alfred C. De Lorme, Maplewood, N. J., and Carl G. Schesch, New York, N. Y., assignors to Western Electric Co., Inc., New York, N. Y., a corporation of New York.

The apparatus covered by this patent relates to the brazing of articles made from an assembly of metallic members and hollow metallic bodies which have non-metallic material, such as glass, sealed thereon and with a fusible material interposed between the hollow metallic bodies and the metallic members.

2,463,408—Machine for Flame-Cutting Circles—Lansing Millis, Ben Avon, Pa., assignor to American Bridge Co.

A special flame-cutting machine is covered in this patent.

2,463,907—Method and Apparatus for Welding Pipe—Roger E. Risley and Paul B. Scharf, Bradford, Pa., assignors to Dresser Industries, Inc., Cleveland, Ohio, a corporation of Pennsylvania.

This patent covers a mobile pipe-welding unit wherein a vehicle carries a torque head which has means associated therewith for gripping adjacent pipe sections and holding the adjacent ends thereof in welding position. Additional means are provided for rotating the pipe sections and for depositing weld beads around the pipe ends to be secured together.

2,464,054—Portable Spot-Welding Gun—Joseph J. Panik, Detroit, Mich., assignor to Banner Products Co., Milwaukee, Wis.

This welding gun includes a pair of terminal rods that have welding points; the rods are pivotally connected together so that the points can be moved toward and away from each other. Actuating mechanism is connected to the rods for effecting pivotal movement thereof and such mechanism includes an elongated leaf spring.

2,464,061—Welding Current Transformer Connection—William A. Soley, Jr., Melrose, Mass., assignor to General Electric Co., a corporation of New York.

Soley's patent covers a main transformer having a multisection primary winding and a secondary winding, wherein a current transformer having a multisection primary winding and a secondary winding is also provided. Each section of a current transformer primary winding is connected in series with a different section of the main transformer primary winding to constitute a plurality of groups of the serially connected sections. Means also are provided for selectively connecting said groups in parallel and in series.

2,464,186—Welding Wire—Albert M. Ross, Westmont, Ill., assignor of one-half to William S. Gilpin, LaGrange, Ill., and one-half to National Cylinder Gas Co., Chicago, Ill.

This patent is on a welding wire which has an elongate core with an enveloping sheath of flux material. An elongate strip extends longitudinally of the core in tortuous form and is embedded in the flux sheathing. A second strip extends longitudinally of the core in superimposed relation to the first strip, being embedded in the flux sheathing. Portions of the second elongate strip are exposed at the surface of the flux sheathing.

2,464,210—Welding Materials and Processes—Charles A. Cadwell, Cleveland Heights, Ohio, assignor to The Electric Railway Improvements Co.,

Cleveland, Ohio, a corporation of Ohio.

This patent covers a welding process and composition. The novel composition is for use in producing molten copper suitable for welding, by a metal-producing exothermic reaction. The composition comprises a mixture of copper oxide with a special reducing agent and with a second reducing agent which contains calcium and silicon. The silicon is present in excess of the calcium and is effective to produce a highly fluid slag.

2,464,402—Apparatus for Controlling Heat in Electric Welding—George E. Kentis, Jr., Cleveland, Ohio, assignor to The Yoder Co., Cleveland, Ohio a corporation of Ohio.

This patent covers a special control circuit that controls heat of an article being welded wherein a photo-electric cell is adapted to respond to the heat condition of the article and such cell is then connected to control means for increasing or decreasing the current supply depending upon the heat of the article.

2,464,528—Apparatus for Welding—Alexander Rava, Jersey City, N. J.

An electric fusion welding circuit is covered in this patent and it includes a condenser, a power transformer, a rectifier tube and means for charging the condenser through the tube. A special transformer for controlling the time of firing of the tube is provided and is connected to the secondary of the power transformer.

2,464,679—Electric Welding Apparatus—Albert C. Fletcher and Donald Lloyd, Oklahoma City, Okla.

This patent covers welding apparatus including a transformer having a primary and secondary winding. Means for obtaining different ranges of output current from the secondary of the transformer are provided and include a reactance. A switch is provided in the reactance circuit and is controllable by the welding operator so that the switch can be closed to short circuit means associated therewith and connected to the reactance for increasing the range of welding current at any desired time.

2,464,752—Chain Welder—Melvin M. Seeloff and Leroy Conklin, Warren, Ohio, assignors to The Taylor-Winfield Corp., Warren, Ohio, a corporation of Ohio.

A special type of chain welding apparatus is disclosed in this patent.

2,464,836—Welding—Royal David Thomas, Jr., Narberth, Pa., and George F. Comstock, Niagara Falls, N. Y., said Thomas assignor to Arcos Corp., Philadelphia, Pa., a corporation of Pennsylvania, and said Comstock assignor to National Lead Co., New York, N. Y., a corporation of New Jersey.

This patent is on a stainless steel welding rod which has a titanium-bearing coating comprising from about 10 to 40% by weight of a powdered alloy containing between 15 and 45% of titanium. Relatively large quantities of aluminum are also present as are percentages of nickel, manganese, copper, silicon and iron.

2,464,875—Chain Welding and Chain Welding Machine—Alfred H. Lewis, Huntington Woods, and Keith Sheren, Dearborn, Mich., assignors to Swift Electric Welder Co., a corporation of Michigan.

This patent relates to a machine for welding together partially open links of a preformed chain.

2,464,906—Indexing Device for Welding Machines—Arthur M. Unger, Chicago, Ill., assignor to Pullman-Standard Car Mfg. Co., Chicago, Ill., a corporation of Delaware.

This patent relates to an indexing device for a welding machine which has a workholding table that is movable in both longitudinal directions.

2,464,925—Welding Flux—Francis Arthur Fox, Swinton, and Edward Frederick Emley, Salford, Manchester, England, assignors to Magnesium Elektron Ltd., London, England, a British company.

This welding flux primarily comprises of lithium fluoride about 20%, magnesium fluoride about 28%, calcium fluoride about 17% and barium fluoride about 35%.

2,464,935—Electrical Welding Control System—Chester E. Leathers, Detroit, Mich.

This patent relates to a system for supplying power to a load circuit, wherein energy storage means are provided and they have a means for delivering charging current thereto. The storage means are connected to the load circuit by connection means which are arranged to maintain the charging means connected to the storage means whenever the storage means are delivering current to the load circuit.

2,464,967—Welding Machine—George M. Dinnick—Bloomfield, N. J., assignor to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

This welding machine has a pair of electrodes both of which are movable toward each other. A workpiece is receivable between the movable electrodes and the apparatus is so constructed that the welding circuit both supplies welding heat to the work between the electrodes and applies a forging pressure of the second electrode toward the work and the first electrode.

2,464,981—Method of and Apparatus for Electric Welding—Chester F. Leathers and Louis M. Benkert, Detroit, Mich., assignors to Progressive Welder Co., Detroit, Mich., a corporation of Michigan.

This patent covers a method of bonding two or more steel members together which comprises passing a heating current therethrough while the members are pressed together to form a weld nugget, measuring the temperature of the welded nugget and sending a second and variable welding impulse through such portion of the members when predetermined temperatures are reached therein.

2,465,157—Oxyelectric Torch—Charles C. Isbell, Long Beach, Calif.

The oxygen-electric torch disclosed in this patent includes a control lever which is manually operable in one direction to effect opening of a valve for oxygen flow through the torch and for the closing of the switch. In its opposite position, the lever closes the valve and also opens the switch.

2,465,242—Gas Torch—Dale A. Line, Bartlesville, Okla.

Line's torch includes a tube which has a mixture of air and gas supplied thereto at one end and a burner head is secured thereto at the other end of the tube. The burner head is tubular and larger in diameter than the mounting tube.

(*Continued from page 494*)

"The Effective Use of Manufacturers' Sales Literature," E. A. Steidl, Product Sales Manager, A. O. Smith Corp., Chicago, Ill.

"The Value of Incentive Bonuses for Inside Employees," Hal Savage, Arizona Welding Equipment Co., Phoenix, Ariz.

The Ladies' Program includes a sightseeing tour of the City of Cincinnati. They are also invited to attend the informal dinner on Thursday evening.

Research Bulletins

The Welding Research Council has inaugurated a new bulletin series to take care of the overflow of research reports not included in the *Welding Research Supplement*. For the most part, this bulletin series will consist of reprints of papers and reports presented before other societies than the American Welding Society. Arrangements have been made with the Society for the sale and distribution of these research bulletins to those members who desire to purchase them. The sale price has been set at $.50 each. The following three bulletins are now available:

No. 1, March 1949—"Steel Compositions and Specifications," by Charles M. Parker, American Iron & Steel Institute.

No. 2, April 1949—"The Nature of the Arc," by J. D. Cobine, General Electric Co.

No. 3, May 1949—"Burn-Off Characteristics of Steel Welding Electrodes," by D. C. Martin, P. J. Rieppel and C. B. Voldrich, Battelle Memorial Institute.

SECTION ACTIVITIES

Prepared by C. M. O'Leary

Anthony Wayne

On the evening of Friday, March 25, 1949, the Anthony Wayne Section held their regular monthly meeting at the Chamber of Commerce Building, Fort Wayne, Ind. The meeting started with a Buffet Dinner at 6:30 P.M., which was followed by a very unusual and interesting entertainment session.

This show was the well-known and highly entertaining General Electric program, "The House of Wonders," presented by M. C. Halleck and Paul Moore of General Electric Works Laboratory. They featured many scientific—not original—wonders such as Plastic Rubber, Chemical Light, Electric Wire Recorder, Various Light and Sound Phenomena, etc., and demonstrated the many uses and tricks that could be done with them.

The Chairman of the Section, George H. Laws, then introduced the technical speaker for the evening, E. J. St. Eve, Design Engineer for the Pandjiris Weldment Co. of St. Louis, Mo., who gave a talk on "Weldment Design." This session was divided into three parts—first, Mr. St. Eve's discussion; second, a series of slides picturing some of the more interesting weldments; and last, a question and answer program.

In his talk Mr. St. Eve traced the tremendous strides the Welding Industry has taken since the days of the First World War up to the present time, stressing particularly the replacing of castings and forgings by weldments. He strongly emphasized the fact that Weldment Design tended, in most cases, to promote the greatest strength, utility and economy obtainable. Like in all new tools, he said, problems are bound to arise but they are being overcome by the ever-increasing knowledge of and practice of Weldment Design.

Following Mr. St. Eve's talk, a number of slides were shown that brought out many thought-provoking questions. After this, a short but very interesting question and answer session was held after which the meeting adjourned.

Ninety members and guests were present and the meeting proved one of the most interesting and educational ones of this season.

Atlanta

February 17th dinner meeting was held in the Meeting Room of Herrin's Restaurant. R. C. Singleton of Nelson Sales Corp., Lorain, Ohio, was the guest speaker. Mr. Singleton spoke on the subject of Nelson Stud Welding, which was very well received. A film on the same subject was shown.

Bridgeport

The seventh meeting of the year was held on Thursday, March 24th, in the Candlelite Restaurant, Bridgeport, Conn. Speaker was John W. Mortimer of The Whitlock Mfg. Co., Hartford, Conn. Mr. Mortimer spoke on "Welding of Nonferrous Metals." He was an excellent speaker and held the audience interest for the entire period of his talk.

Chattanooga

"Inert-Arc Automatic Welding" was the subject of H. T. Herbst's talk at the March 1st dinner meeting held at Edgerton's Dutch Manor. Mr. Herbst is connected with The Linde Air Products Co., Newark, N. J. A film "Arc Action During Welding" was shown in conjunction with the paper. Both the talk and the film were well received.

The April meeting was held on the 4th at Edgerton's Dutch Manor.

A. B. Tesmen, Welding Engineer with the North American Phillips Co., Inc., presented a paper on "Contact Arc Welding." His talk was emphasized with slides portraying comparative qualities of contact rods and conventional rods.

Chicago

Observations noted while on a postwar trip through the South Pacific seeking scrap sources were included in a thorough explanation of the problems and processes of modern scrap preparation in a talk by Howard Parker, Carnegie-Illinois Steel Corp., at the March 18th meeting. Speaking in the People's Gas Light and Coke Co. auditorium, Mr. Parker said there is not as much usable scrap in war areas as is generally believed. Shipping costs, quality of metal and preparation problems rule out many possibilities.

After scrap is received at the mill, it must be carefully sorted, Mr. Parker pointed out, as to chrome, manganese, etc., content, because of oxidizing and nonoxidizing qualities.

The domestic scrap situation seemed to be easing, in Mr. Parker's opinion, and scrap shipments from overseas will probably be cut down as a result. German scrap is heavy and of good quality, but needs careful sorting, he said, because of explosives and chemicals mixed in some shipments.

William Pearson presided over the meeting in the absence of Chairman Charles Steele. Ted Russell gave a report on the officers nominated for president and vice-president of the "Fusioneers." R. L. Kohlbry, as chairman of the Nominating Committee, read the names of men selected for officers for the year 1949–1950. Dr. John M. Parks, chairman of the Membership Committee, reported on the committee activities.

The premeeting dinner was held at 6 P.M. at Burke's Grille and Restaurant with about 50 in attendance. Before the meeting was called to order in the auditorium, three movies were shown, "Wheels A-Rolling," a color of the Chicago Railroad Fair, "Bryce-Zion-Grand Canyon" and "Banff-Lake Louise."

Cincinnati

Regular monthly meeting of the Cincinnati Section was held on Tuesday, February 22nd, at Engineering Society Headquarters. The subject "Power Supply for Heliare Welding" was presented by John H. Blankenbuehler, Design Engineer, Hobart Bros. Co. Slides were also used to illustrate the talk. Mr. Blankenbuehler presented a very good talk.

Sixty-six members and guests were present. Following the meeting a "Dutch Lunch" was served.

Colorado

Dinner meeting was held on March 8th in the Range View Rooms, Silver Wing Inn, Denver. Patrick J. Patton, Sales Supervisor, Ransome Division, Worthington Pump and Machine Corp., gave a talk on the History and Development of Turning Rolls and Positioners in the Welding Industry.

A film "Travel with American Air Lines in Old Mexico" was also shown.

Columbus

The Columbus Section had its most successful meeting March 11th. The plant visit sponsored by the Marion Power Shovel Co. was extremely well organized. Small groups escorted by "The Shovel" personnel gave the visitors a chance to ask questions and see the different phases of operation in the fabricating of the huge 45-cu. yd. shovel.

At the conclusion of the plant tour the visitors assembled at the Harding Hotel for dinner.

Guest speaker was Leon C. Bibber of the Carnegie-Illinois Steel Corp., Pittsburgh. Mr. Bibber commented on how well organized the visit was and thanked Howard Cary and Amel Meyer for their efforts.

Mr. Bibber opened his talk with an experiment showing recalescence, then went on to explain some of the effects of heating and cooling in welding. This paper was extremely well presented and comments were to the effect that this was the best talk of the year.

At the conclusion of Mr. Bibber's talk,

Mr. Busick showed a film on the Marion Power Shovels at work. This was very interesting.

Visitors to this session came from many parts of the area, all interested in the welding of heavy equipment.

Dayton

Carl McLaughlin, head of the Engineering Service Division of Tube Turns, Inc., Louisville, Ky., addressed the March 23rd meeting, held at the Engineers Club, on the subject "Piping Developments, a Challenge to the Welding Profession."

Mr. McLaughlin and the members of his staff are engaged in developing new applications for welded piping, in a variety of fields. Their recommendations have led to new efficiency in the piping systems of many well-known manufacturing establishments, and in piping for industrial equipment.

Detroit

"Welding Research—Its Value to Industry," was the subject of the March 10th and 11th meetings of the Saginaw Valley Division and Detroit Section.

Speakers and Subject for the evening were: Dr. Wendell F. Hess, Dept. of Metallurgical Eng., Rensselaer Polytechnic Institute, "Welding Research Its Value to Industry"; George Martin, Kilpatrick and Martin, "What Welding Research Can Do for the Resistance Welder Manufacturer"; Jack Ogden, Charge of Welding Research Developments, Fisher Body Division, General Motors Corp., "What Welding Research Can Do for the Automotive Manufacturer."

Dr. Hess, in his own inimitable style, presented the principal address of the evening. He urged support of research and then went on to clinch his point by pointing out the valuable facts which have been discovered and published in various issues of THE WELDING JOURNAL, where they are available to members of the AMERICAN WELDING SOCIETY. His talk was fully illustrated by an adequate collection of slides, of photographs, charts and curves, which appeared with the articles.

These showed the results and facts which research has developed in various phases of welding, and how widely their endeavors have touched the welding field.

George Martin and Jack Ogden told of what they and their firms were doing in the field of research and expressed the need for more work and men in research such as Dr. Hess.

Hartford

February 17th dinner meeting was held in the Whitlock Mfg. Co. Cafeteria. Speaker of the technical session was Harold Robinson of the Air Reduction Laboratories, who spoke on the subject, "Hard Surface Electrodes." Discussion followed Mr. Robinson's very interesting address.

March 17th dinner meeting was also held in the Whitlock Mfg. Co. Cafeteria. E. C. Korton of Hartford Steam Boiler, spoke on the subject "Stress Analysis" and gave a demonstration with a Photoelastic Polariscope.

L. T. Benoit of Flame Treating & Eng. Co., gave a blackboard demonstration of "Flame Hardening."

Lehigh Valley

The regular monthly meeting of the Lehigh Valley Section was held on Monday, March 7th, at the Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pa. C. L. Kreidler, Chairman, presided.

Charles D. Cooper, District Manager, Metal and Thermit Corp., gave an illustrated talk on "The Thermit Welding Process." Mr. Cooper presented an interesting discussion on the types of jobs to which the Thermit welding process is applicable. He told of the work being done in shipyards on the fabrication of heavy castings, and the use of the process for joining of rails and general repair work.

In the discussion that followed the talk, Robert Brown, of the Metal and Thermit Corp., ably answered many questions from the audience.

Los Angeles

Thursday evening, March 17th, the Los Angeles Section held its regular monthly dinner meeting. The speaker was Dr. D. C. Smith, Chief Metallurgist, Electrode Division, Harnischfeger Corp. Dr. Smith spoke on the subject "Welding—New Techniques." Discovery and development of arc welding was described first, with more recent applications and techniques following. In this manner the background was shown for the necessity of producing such a type as the low hydrogen electrode. Applications of an inert gas shield to exclude hydrogen from the weld area were also discussed. Uses of low hydrogen coatings were further described and properties attained illustrated upon slides. Dr. Smith's straightforward answers to questions and divulgences of information sometimes considered trade secrets were greatly appreciated.

Louisville

J. Lyell Wilson, Director of Research, American Bureau of Shipping, New York, was the guest speaker at the March 22nd meeting. His subject was "Inspection and Quality Control of Welded Construction."

A part of Mr. Wilson's talk was illustrated with lantern slides and was a well-presented discussion of research in improved designs for the hatch corners of welded ships. Data was also given on the development of ship plate steels for better low temperature performance.

Following the discussion period, a movie about magnesium, entitled "Treasure from the Sea" was shown.

A Dutch Lunch was served at the end of the meeting.

Mahoning Valley

R. H. Davies, Consulting Engineer of The Lincoln Electric Co., Cleveland, Ohio, was the guest speaker at the March 15th meeting held in the Ohio Edison Auditorium, Youngstown, Ohio.

Mr. Davies' talk "Design and Welding of Machinery Structures" pointed out the "know-how" in welding machinery structures.

Approximately 10 million tons of cast iron produced in this country annually challenges the welding engineer when it is recognized that 2½ million tons should be replaced by fabricated welded steel structures. Such industries as the machine tool, textile machinery, etc., should have many parts and, in fact, whole machines fabricated from welded steel because of greater rigidity and lower cost.

February 18th Meeting, Maryland Section

The many reasons why such machines are not built of welded fabrication are overshadowed by one—lack of design "know-how."

Mr. Davies concentrated on the type of design "know-how" as the simplest way to indicate how structures can be welded fabrications.

Maryland

The February 18th meeting of the Maryland Section was held in the Engineers' Club, Baltimore, with 115 attending. The technical speaker was Professor Robert T. Pond, Assistant Professor of Mechanical Engineering, Johns Hopkins University, who discussed, "The Heat Effects of Welding." Professor Pond enlightened those in attendance on phase diagrams, crystalline structure and changes of structure, pointing out the effect of these on welds and welded structures.

This meeting was designated as "Joe Humberstone Night" and was set aside to honor J. H. Humberstone for his services, leadership and wise council to the A.W.S. Mr. Humberstone's influence has not been limited to the Maryland Section, but also included the National A.W.S., having been District Vice-President in 1942–43, and at the present time, is a director of the A.W.S.

The dinner, at which 86 were in attendance, and the period usually given to after-dinner entertainment, were given to honoring Mr. Humberstone.

S. A. Greenberg, Technical Secretary of the A.W.S., and C. A. Loomis, Bureau of Ships, Navy Department, were special guests invited to tell of Mr. Humberstone's contributions to welding. In recognition of Mr. Humberstone's contributions, the Section presented him with an A.W.S. pin, welded stainless steel book ends, and a citation reading: "Citation, awarded to J. H. Humberstone for his outstanding service, loyal support and generous contributions of time and thought to the Maryland Section of the A.W.S., J. H. Humberstone Night, Feb. 18, 1949," and signed by the Section Officers.

Mr. Humberstone is soon moving to New Jersey where he has accepted a position with the Air Reduction Co., as Director of Apparatus Manufacturing.

Michiana

The Michiana Section held their seventh meeting of the current series on March 17th, with A. E. Hackett, Progressive Welder Co., doing the honors. Following a very brief history of the resistance welding industry, Mr. Hackett had members of the audience write out any problems that they might be up against in resistance welding. Using these as a basis for discussion, he then elaborated upon the points which the questions brought up. The discussion was preceded by a movie on "Radiography" and followed by General Electric's picture, "This Is Resistance Welding."

Milwaukee

About 60 members attended the dinner preceding the March 25th meeting of the Milwaukee Section held at the Ambassador Hotel. Others came in later for the technical meeting which was addressed by W. R. Plummer, Sales Manager of the Progressive Welder Co., Detroit.

Mr. Plummer's talk covered some of the fundamentals of designing for resistance welding and was of a very practical nature. He explained how the speed and cost of producing weldments by resistance methods are affected by design, and he emphasized the desirability of the designing engineer being thoroughly familiar with the requirements for good resistance welding setups. The effects of proper spacing of the welds, flange widths and the use of projecting welding were discussed in an interesting manner. Flash welding was mentioned but not discussed in detail.

Nashville

March dinner meeting of the Nashville Section was held on the 4th at the Nashville Bridge Co. Cafe. H. T. Herbst of The Linde Air Products Co., presented a clear-cut, interesting talk on "The Development and Application of Heliare Welding Process." A slow motion film on the Characteristics of the Arc was also shown and well received.

New Jersey

Harry W. Pierce of the New York Shipbuilding Corp., Camden, N. J., gave a very interesting talk at the March 15th meeting. While making a survey of the Japanese shipbuilding industry for the U. S. Government, Mr. Pierce had the opportunity of seeing more of their industrial facilities than most of our occupational personnel.

One of the most significant facts was that with few exceptions the Japanese did not expand their industries for wartime production. The war was planned far in advance, and in the early 1930's, they started stockpiling huge stores of finished munitions. When they felt that there was enough to fight a war, they started hostilities. When the war came to an end, they still had a well-equipped army of millions of men with supplies and equipment for about two more years of fighting. Fortunately for us, their policy resulted in much of their fighting equipment being obsolete, and it did not equal our modern wartime production.

They performed little or no maintenance and repair work during the war, and their plants were impressive with their untidiness.

The present problem is an acute shortage of major resources with which to supply and feed the population. There are no resources for the production of goods for foreign exchange, which imposes a serious handicap for economic recovery.

New York

At a joint meeting with the American Society of Civil Engineers, the New York Section heard LaMotte Grover, Welding Engineer, of Air Reduction Sales Co., speak on "Welded Steel Structures" at the Engineering Societies Bldg. on March 16th.

Mr. Grover discussed recent developments and practical applications of structural welding. He used as examples some of the welded buildings, gas holders and bridges that are now being constructed and with slides he showed some joint designs. Mr. Grover also discussed the role that research in the United States and abroad is playing in orienting practices of design and construction procedures.

Over 250 members of the two Societies were present. R. W. Armstrong, President of the Metropolitan Section of the A.S.C.E., introduced the speaker and conducted the discussion period. Arrangements for the meeting were made by H. W. Lawson, 2nd Vice-Chairman of the A.W.S. New York Section.

Northern New York

A special meeting of the Northern New York Section was held on Friday, March 11th. Arsham Amirikian, Head Designing Engineer of the Bureau of Yards and Docks of the U. S. Navy, spoke on "New Trends in the Design of Welded Steel Structures." The meeting was held in the auditorium of the New York Power and Light Co. Bldg., Albany, to facilitate attendance by structural engineers of the New York State Department of Public Works. The meeting was called so as to coincide with Mr. Amirikian's schedule as visiting lecturer at the Rensselaer Polytechnic Institute at Troy. Mr. Amirikian lectures at Rensselaer each year in connection with the training of young officers in the Civil Engineering Corps of the U. S. Navy. Mr. Amirikian discussed welded rigid frame structures and articulated wedge beam framing. His talk was illustrated by numerous slides. The meeting was well attended by structural engineers associated with various organizations in the area.

Northwestern Pennsylvania

"Stump the Experts" night was held on March 22nd at the Erie, Pa., Y.M.C.A. The experts were G. O. Hoglund, Chas. H. Jennings, C. W. Lytton and B. J. Grimes. There was also a welcoming delegation from Niagara Frontier Section headed by Chairman Isadore Morrison. A visit and talk was made by Fred L. Plummer, Vice-President, District No. 4.

Oklahoma City

The Oklahoma City Section held its March meeting on the evening of March 9th at the Huckins Hotel in the Crystal Room. This was a dinner meeting, with an excellent turnout of 42 men to hear "Connie" Voldrich of Battelle Memorial Institute give his talk.

The subject of his talk was "Weldability of Steels." He utilized slides and did an excellent job of presenting his subject.

As an added attraction, arrangements were made with the Oklahoma State Highway Patrol to have Lieut. Lester give a short coffee talk on the subject of Safety. This subject is of general interest and extreme importance and it too was well received.

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Philadelphia

A Panel meeting was held on March 4th at the Engineers Club in the form of a debate on the subject "Resolved That Present Welding Codes and Specifications Should Be Liberalized." Affirmative—George Johnson, Lincoln Electric Co., and Harry Irrgang, W. K. Mitchell Co. Negative—T. M. Jackson, Sun Shipbuilding & Dry Dock Co., and R. D. Bradway, New York Shipbuilding Corp. Use of debate for this type of meeting proved very interesting and was well received.

"How to Select the Best Welding Process for the Job" was the subject presented by Walter Mehl, Welding Engineer, Heintz Mfg. Co., Philadelphia, at the regular monthly meeting held on March 21 st.

Mr. Mehl covered the subject of selection of the best welding process in an able manner.

After outlining the general considerations involved, he illustrated with projected photographs various types of jobs that had been undertaken by Heintz and gave the reasons for using particular welding processes on that job. The importance of using the proper welding process for both the best results and economy were emphasized.

Pittsburgh

The monthly dinner meeting was held on March 16th at Mellon Institute. Dinner was enjoyed in the Hunt Room of the Hotel Webster Hall. Rodger J. Metzler, Development Engineer, Handy & Harman, New York, presented an excellent address on "Low-Temperature Silver Alloy Brazing." An educational film on Silver Alloy Brazing was shown in conjunction with the paper. This was very good. Over 80 members and guests were present despite the unfavorable weather.

Puget Sound

The regular dinner meeting of the Puget Sound Section was held on March 23rd at the Hotel Gowman. De Witt C. Smith, Chief Metallurgist, Electrode Division, Harnischfeger Corp., Milwaukee, spoke on "New Techniques in Welding." Mr. Smith gave some very interesting facts regarding Inert-Gas Process and the use of Low-Hydrogen Electrodes. Both subjects were well presented and held much interest for the group. A number of questions were answered and a good discussion resulted.

A short picture by General Electric Co. on Jet Propulsion was shown.

St. Louis

Regular monthly dinner meeting was held on Friday, February 11th, in the Forest Park Hotel Ballroom. "Oxyacetylene Cutting, Scope, Methods and Equipment" was the subject presented by R. F. Helmkamp of the Air Reduction Sales Co., Machine Gas Cutting Division. Fifty-eight members and guests were present and all participated in the discussion. Two series of colored slides were shown. Mr. Helmkamp's talk was very well received. Mr. Helmkamp has had a wide experience in all phases of the subject.

The March meeting was held on the 11th in the Forest Park Hotel Ballroom. William J. Phillips, Director, Production Development Dept., Steel Founders Society of America, spoke on "The Production of High Quality, Low Cost Parts for Industry." Lots of interest was shown in Mr. Phillips' talk and slides.

San Francisco

March 21st meeting of the San Francisco Section was held in the Engineers Club. D. C. Smith, Chief Metallurgist Electrode Division, Harnischfeger Corp., Milwaukee, was the speaker. His subject was "Welding—New Techniques." Fifty-nine members and guests were present.

Outlining new techniques in welding, Mr. Smith told the group the improvement of both machines and electrodes for electric arc welding during the first World War gave the first real impetus to structural welding. This new technique has made it possible to make weldments satisfactorily without a preheat, which a few years ago was considered impossible. Mr. Smith also stated that very high-tensile electrodes capable of making welds in heavy structure of high-tensile steels without a preheat are showing promising results.

South Texas

Roger J. Metzler of Handy & Harman, New York, was the guest speaker at the February 11th dinner meeting held in Ben Milam Hotel, Houston Tex. Mr. Metzler presented a clear-cut, interesting paper on "Design for Silver Alloy Brazing." A film on Silver Alloy Brazing was also shown.

A motion was made and unanimously carried, that a committee of three be appointed to assist the City of Houston in revising the city building codes; and that this committee recommend to the city the adoption of the A.W.S. standards.

A. E. Wisler, Chairman of the Section, duly appointed W. H. Greer, P. D. Morgan and S. C. Hamilton as members of this committee.

The March 11th dinner meeting was also held at the Ben Milam Hotel, Houston. C. B. Voldrich of Battelle Memorial Institute, Columbus, Ohio, spoke on Welding Metallurgy.

Toledo

The regular meeting of the Toledo Section was held on March 9th in the Commodore Perry Hotel and was indeed very enlightening.

The distinguished guest speaker, Prof. Wendell F. Hess, Head, Department of Metallurgical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y., and a former president of the A. W. S., spoke about "What Welding Research Can Do for Industry."

He called research the life blood of any organization and "we should all know that these words are very true, for it is because of this research that today we can make sound welds on almost any metal." It has helped develop special processes, which are now everyday jobs.

Prof. Hess used slides to show the setup of welding research equipment at R.P.I. Other slides gave the results obtained from tests in the form of tables and graphs. Equally important was his translations by explanation in understandable English of this collection of technical data.

The "Arc Welding Conference" held on March 22-24, sponsored by the Toledo Section, proved apparently to be successful. The average attendance of each evening was approximately 100, which was more than expected. R. H. Davies, the speaker, very ably brought out the shortcomings and the more correct ways of modern design for welding in most of its phases.

Washington

The Washington Section held its March dinner meeting on the 29th at O'Donnell's Restaurant, Washington, D. C. The meeting was held in the Pepco Auditorium. A. N. Kugler and E. H. Roper of the Air Reduction Sales Co. were the speakers. Their subject "Developments in Inert-Gas Arc Welding" gave a description of the Airco Heliwelding and Aircomatic Processes.

Western Massachusetts

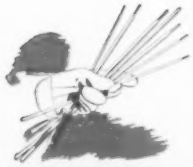
On Tuesday, March 15th, at the Sheraton Hotel in Springfield, about 17 members and guests met for a round-table discussion of welding problems. The conference was chairmanned by Roger Tuthill of the General Electric Co., and chairman of the Section. Among the problems discussed were the welding of white metals, for which it was recommended that a slightly reducing gas flame be used after grinding off all plating. The cleaning of stainless welds to produce a bright, high quality surface was a topic raised during the meeting. Mechanical methods such as sandblasting or wire brushing seemed to produce the best results on large items of equipment, it was pointed out. Developments in shielding of high-frequency inert-arc welding were mentioned, along with relationships with the Federal Communications Commission, which has assigned certain frequencies for the use of the welding trades.

Wichita

The Wichita Section held its March meeting on the 14th at the Broadview Hotel. Guest speaker was P. J. Patton, Regional Supervisor, Welding and Assembly Positioning Equipment Division, Worthington Pump & Machinery Corp., Dunellen, N.J. Mr. Patton's subject was "Adaptation and Use of Positioners in Welding."

Worcester

Merits and limitations of structural welding, as compared to riveting, were analyzed by Frederick H. Dill of Ameri-



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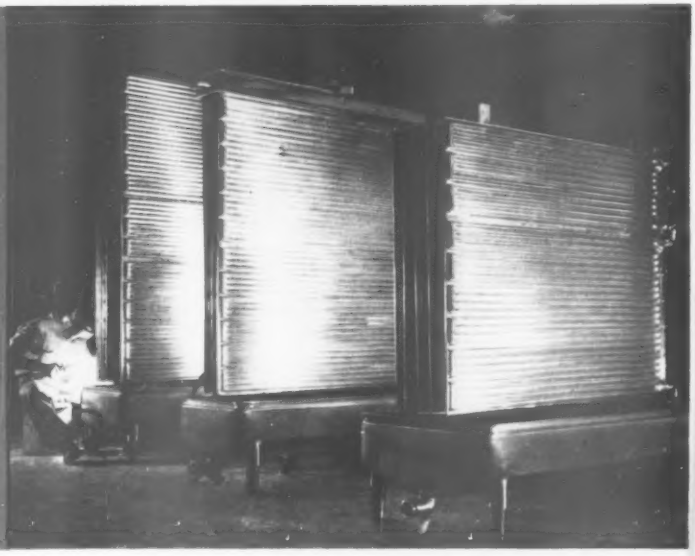

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can Bridge Co., Ambridge, Pa., at a dinner meeting of the Worcester Section held on March 28th in the Coronado Hotel.

Mr. Dill said that welding codes of THE AMERICAN WELDING SOCIETY and the American Institute of Steel Construction had become nationally accepted as the basis for state and municipal regulations.

"Steel—Man's Servant," a color sound-movie furnished through the courtesy of the American Steel and Wire Co., was shown and enjoyed.

LIST OF NEW MEMBERS

March 1 to March 31, 1949

ANTHONY WAYNE
Richmond, Rex E. (B)

BIRMINGHAM
Loewen, Roland Phillip (C)

CHATTANOOGA
Davis, Henry E. (C)

CHICAGO
Baker, B. R. (B)
Cameo, Robert M., Sr. (C)
Forss, John E. (C)
Joyce, Charles F. (C)
Lockefer, Frank V. (B)
Mulder, Henry (C)
Pittman, D. H. (C)
Schwenk, Earl F. (C)
Young, Otis H. (C)

CLEVELAND
Baker, V. O. (B)
Jacobson, Martin (D)

COLORADO
Leenerts, F. E. (C)
Saurini, Earl (B)
Smay, John (C)
Weinberger, E. W. (B)

COLUMBUS
LaPlante, C. A. (C)

DAYTON
Stafford, Chester F. (B)

DETROIT
Botterill, John W. (B)
Brinson, Adolph M. (C)
Brown, James (C)
Decorek, Walter (C)
Fagge, Ralph Dean (B)
Fors, William J. (B)
Gallagher, Frank (C)
Gilman, David F. (C)
Hartwick, Glenn, E. (B)
Holtzhouse, Irvin L. (B)
Holtzhouse, Paul E. (B)
Jurkiewicz, John J. (B)
Jurkiewicz, Norbert P. (B)
Kelly, Martin J. (C)
Lillie, Herbert (C)
MacKay, John Walker (C)
Martin, Robert (C)
McDonald, Wm. Walter (B)
McGregor, William O. (B)
Mohrman, A. W. (B)
Morton, Louis H. (B)
Munz, Elmer G. (B)
Odell, Pearl L. (C)
Paulinski, Stanley L. (C)
Rains, Roy R. (B)
Rankin, Roy S. (B)
Seid, Howard R. (C)
Thompson, Harvey R. (C)
Trella, John (C)
Walker, Robert E. (C)
Wreford, Fred. S. (B)
Wreford, John S. (B)
Zanichelli, Joe M. (C)

HARTFORD
Cameron, John H., Jr. (B)
Chadwick, D. W. (C)
Person, E. Hjalmar (C)
Zielinski, Sigmund (B)

INDIANA
Gelling, Homer R. (C)
Johnson, Alvin B. (B)

KANSAS CITY
Conroy, T. G. (B)
Gander, A. E. (C)
Young, Charles E. (C)

LEHIGH VALLEY
George, Harold W. (C)
Skrivanek, Gustave (C)
Von Blohn, Henry C. (C)

LOS ANGELES
Bemmer, Albert J. (B)
Larkin, Ralph, Jr. (B)
Wilson, Paul T. (C)

MAHONING VALLEY
Dixon, Wm. G. (B)

MARYLAND
Bradley, Joseph A. (C)
Donoho, William H. (C)
Nelson, James O. (C)
Rayfield, Robert N. (C)
Weaver, Henry G. (C)

NASHVILLE
Koellein, Charles L., Jr. (B)

NEW JERSEY
Chorney, Harold (B)

NEW YORK
Calabrese, Sam J. (C)
Cardillo, Charles A. (C)
Ferrigno, Julius (C)
Jacobsen, Edwin H. (C)
McInerney, H. F. (C)
Montanaro, Stephen A. (B)
Striplin, James M. (C)
Watson, Lloyd B. (C)

NIAGARA FRONTIER
Baumler, Donald F. (C)
Bos, Peter H. (B)
Chapin, Frank A. (B)
Crandall, Therold L. (C)
Ford, V. E. (B)
Kasper, Andrew P. (C)
Livingston, R. H., Sr. (A)
Lorenzini, Anthony (C)
O'Donnell, M. T. (A)
Petersen, Harry W. (C)
Roof, K. A. (C)
Schattenberg, R. W. (B)
Stahl, Leslie W. (C)
Straub, Edward C. (C)

NORTHERN NEW YORK
Barrie, Charles (C)

NORTHWEST
Neemes, J. C. (C)

OKLAHOMA CITY
Walcott, Jack (C)

PHILADELPHIA
Berry, Edward H., Jr. (B)
Butterwick, Robert (C)
Craig, Frank E. (C)
Feustel, Arthur B. (B)
Gale, Allen A. (B)
Gedecka, Bernard J. (C)
Hussey, Frank W. (C)
Martin, Walter F. (C)
Mulligan, Martin A. (C)
Overton, C. N. (B)

PITTSBURGH
Birmingham, G. W. (B)
Boyer, Ross J. (C)
Braut, E. B. (C)
Forsman, C. J. (B)
Gaynor, Theodore (B)
Golik, Mark A. (C)
Hall, Robert Llewellyn (C)
Kennedy, Thomas E. (C)
Menaul, Robert F., Jr. (C)
Wilson, George P. (C)
Young, Eric R. (B)

PUGET SOUND
Bank, Mark P. (C)
Edwards, Edward J. (C)
Johanson, Folke (C)
Luetke, J. A. (C)
Pease, Willard E. (C)

ST. LOUIS
Doran, A. V. (C)

SAN FRANCISCO
Coonley, H. E. (C)

SOUTH TEXAS
Burns, Corbit (C)

WASHINGTON
Keller, Howard Lee (C)
Talbot, Frederick A. (C)

WESTERN MICHIGAN
Carrigan, W. H. (B)
Flenar, Otis M. (C)
Keener, A. Jack (B)
McClellan, W. W. (B)
Naser, Albert W. (C)
Sharp, Stephen (C)
Wolfinger, Regis (C)

WICHITA
Browne, S. G. (C)

WORCESTER
McDonald, Edward R. (C)

YORK-CENTRAL PA.
DeLong, William T. (C)

NOT IN SECTIONS
Blank, Milton K. (C)
Brenner, Udell N. (C)
Daffunchio, Agustin Felix (C)
Dame, J. T. (C)
Fronk, Robert W. (C)
Geikler, J. A. (C)
Hainer, Linton (C)
Holt, Henry H. (C)
Kemp, Antone B. (C)
Kreamer, W. H. (C)
Lanouette, Yves (C)
Markle, Prentiss B. (D)
Maxwell, E. G. Staley (C)
Morris, M. L. (C)
Pugh, M. F. (C)
Richardson, David H. (C)
Rose, W. E. (C)
Simpson, Richard M. (D)
Smith, Garlin L. (C)
Watts, R. T., III (B)

Members Reclassified

During Month of March

CHICAGO
Tracy, Stark E. (C to B)

DETROIT
Holtzhouse, Guy A. (C to B)

NEW JERSEY
Aborn, R. H. (C to B)

WESTERN MICHIGAN
Kline, Robert E. (C to B)

WELDING RESEARCH COUNCIL

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Supplement to The Welding Journal, May, 1949

Evaluation of Effect of Residual Stresses

Welded test plates, approximately 3 feet square with reproducible defects such as notches, were tested in the as-welded state and with low-temperature stress relieving and with furnace stress relieving by bending at different temperatures. Low temperature stress-relieving or furnace stress relieving of welded structures gives considerable assurance against premature failure

by T. W. Greene

Abstract

In this investigation, an attempt was made to evaluate the effect of residual stresses upon the mechanical properties of welded plates. In order that the welding conditions and the resultant stresses might be nearly comparable to field conditions, relatively wide weldments (approximately 3 ft. square) were used. During welding, reproducible defects, such as notches and triaxial stress raisers, were included in the welds. In a few preliminary tests, cracks with carefully controlled dimensions were purposely made at weld intersections. When these weldments were tested in the as-welded state by bending at −20° F., they developed fractures at 3000 to 10,000 psi. Plates that were stress relieved by the low temperature method at 350° F. or furnace-treated at 1200° F. all sustained loads well above the yield point of the material.

In a more comprehensive series of tests, a large number of bend tests were made at various temperatures from −60 to +40° F. All specimens were 3 ft. wide and cut from one large plate. These plates contained a longitudinal weld with a reproducible transverse defect (a saw-cut notch made with a small jeweler's saw). On testing, certain of these plates showed transverse bead cracks. When the plates were tested in the as-welded condition at low atmospheric temperatures (−20 to +20° F.), they failed in a brittle manner with little or no deflection under bending stresses from 0 to less than 17,000 psi. The zero load is indicated by one plate that cracked as it was being cooled for testing.

The plates in the as-welded condition sustained bending loads above the yield point only if the temperature was above +40° F. In contrast, plates that had been stress relieved by the low-temperature method or in the furnace, sustained loads well above the yield point even at temperatures as low as −60° F. The transition or embrittlement temperature in these plates as indicated by load carrying capacity and deflection was improved, that is, lowered more than 100° F. (from +40 to −60° F.), by stress relieving.

The data presented indicates that either low-temperature stress relieving or furnace stress relieving of welded structures gives considerable assurance against premature failure.

T. W. Greene is a Welding Engineer with The Linde Air Products Co., New York, N. Y.

This paper was presented at the Twenty-Ninth Annual Meeting, A.W.S., Philadelphia, Pa., week of Oct. 24, 1948.

INTRODUCTION

EVALUATING the effect of residual welding stresses on the service performance of a structure is admittedly difficult and many investigations have led to controversial interpretations. Large numbers of static tests of welded structures have been made with the object of determining the conditions under which residual stresses may contribute to fracture. Some of these would seem to justify the opinion held by many that residual stresses have little or no influence. Nevertheless, many fractures have occurred in practice during the welding of engineering structures that could only be explained by assuming that residual welding stresses contributed to the failure.

There seem to be some fundamental reasons why numerous investigations have not been more fruitful in correlating laboratory results with known field conditions and service experience. One characteristic reason is the small size of the specimens used in laboratory tests. We cannot expect residual stresses to be present to any appreciable extent in the small specimens prepared for the reduced tensile, impact, or slow bend tests or in test weldments which are frequently 4 to 6 in. wide.

Another reason is that many tests have carried stresses above the yield point thus eliminating the effect of residual stresses. A few investigations will be mentioned in an attempt to illustrate these and other features without any intent of criticism of the investigations.

Prof. Wilson and Chao-Chien Hao[1] report tensile tests on specimens that are 40 in. wide by 15 ft. overall as shown in Fig. 1. Tests were made of prime plate and of plates with longitudinal welds made by the Unionmelt process and by metal arc welding. Specimens were tested in both the as-welded condition and after low temperature stress relieving. All samples were taken from the same heat of steel. These specimens were wide enough to demonstrate the effect of residual stresses, but no differences in fracture strength were found. However, it should be noted, that the welds were free from defects (as shown by perfect X-rays) and the method of testing itself obliterated any effect of residual stresses, since it carried the stresses above the yield point.

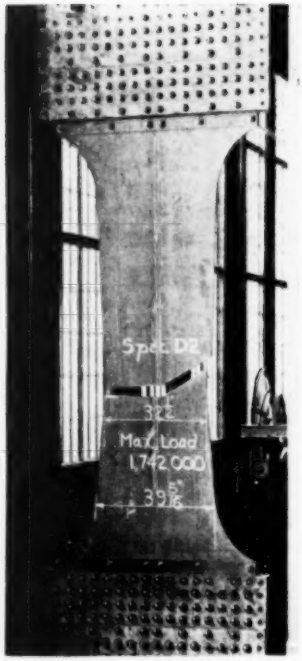


Fig. 1 Tension tests of 40-in. wide, ¾-in. thick prime plate and longitudinal welded specimens as-welded and low-temperature stress relieved. All welds X-rayed, from W. M. Wilson and Chao-Chien Hao

One of the main problems in laboratory testing has been the extreme difficulty of isolating the effect of residual stresses from other metallurgical factors. Kennedy[2] in a series of tests to investigate "Some Causes of Brittle Failure in Welded Mild Steel Structures," made notches in the welds and weld beads with a $^1/_{16}$-in. wide milling cutter. Most of the bend test specimens were only 4 in. wide and the results did not seem to indicate too much influence of residual stress although the effects of other metallurgical factors were clearly demonstrated. The narrow specimens were stress relieved by stretching them 2% (well above the elastic limit) which probably caused some metallurgical damage. Wider specimens which were thermal stress relieved by heating the plate on both sides of the weld, seemed to give better results. Kennedy, however, was able to demonstrate clearly by laboratory experiments that a reaction or assembly stress, set up by welding, in a structure of mild steel plate, can actually cause fracture to occur.

Flanigan[3] in his investigation of the ductility of arc welds conducted a large number of bend tests at −40° F. He used specimens 6 in. wide having a bead deposit, which was transversely notched, with a U-shaped notch having a radius of $^1/_{16}$ in. As a part of his investigation he tested mechanically stress-relieved specimens in an attempt to determine the effect of residual stresses. These exhibited very low ductility as shown by the small angle of bend. Again, these specimens were prestrained or stretched 2½% to relieve stresses. He points out the metallurgical damage that such plastic straining may do to some steels.

There is little published information on the effect of residual stresses on fatigue strength. However, one very interesting article was recently published on this subject by L. D. Hall and E. R. Parker.[4] They made fatigue tests on specimens $^3/_4$ in. thick by 4 in. wide with a welding bead on each side ground flush. Half of the specimens contained residual welding stresses and half were free of stresses. This phase of the investigation indicated that residual welding stresses had no effect. The fatigue limit of both types (stressed and stress relieved) was 15,000 psi. compared with approximately 25,000 psi. for the base metal. Here again the residual welding stresses were removed by stretching 1% which might have some bearing on the results. In the second phase of the investigation, Hall and Parker conducted fatigue tests of unwelded notched plates. Again, half of the specimens contained residual stresses and half were stress free. The residual tension stresses of undetermined magnitude were induced by heating the edges of the plate to 500° F. The nominal fatigue limit of the notched specimens was reduced from about 12,700 to 6400 psi. by the residual stresses (a reduction of about one-half).

It has been shown that many of the structural failures that have occurred in construction or service have been caused by stress concentrations or stress raisers resulting from design or geometry or from notches, many of which are in the nature of weld defects. Design failures can and must be corrected; notches and defects can be minimized by knowledge and vigilence. To produce stress raisers many investigators have used artificial notches such as saw cuts and the like. Due to the obvious difficulty of producing notches internally, such notches have generally been made on the surface. In order to evaluate the effect of residual welding stresses, the notch or defect should be internal if possible and should preferably be incorporated in the weld and subjected to the same cycle of straining as the weld and adjacent metal. Naturally, these conditions will not be met if the test defect is produced after the weld is made. If possible, the defects hould also be sufficiently severe to produce failure below the elastic limit under applied loads at normal atmospheric temperature, otherwise the effect of residual stresses may be obliterated.

In this discussion it is not intended to imply that all residual stresses are harmful. They seem to have no influence in many engineering structures, as, for example, rolled structural shapes. If used wisely, they may be of great benefit in prolonging the life and improving the service of many engineering structures. Examples of useful stresses are the shot peening of known points of stress concentration on the surface to put the area under residual compression, the rolling-in of boiler tubes and heat exchanger tubes, and the autofrettage of guns and thick wall containers where the internal fibers which

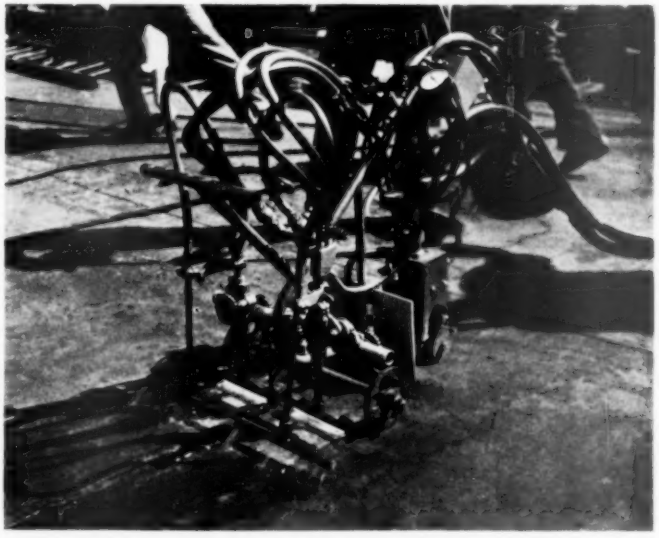


Fig. 2 Low-temperature stress-relieving deck welds of T-2 tanker

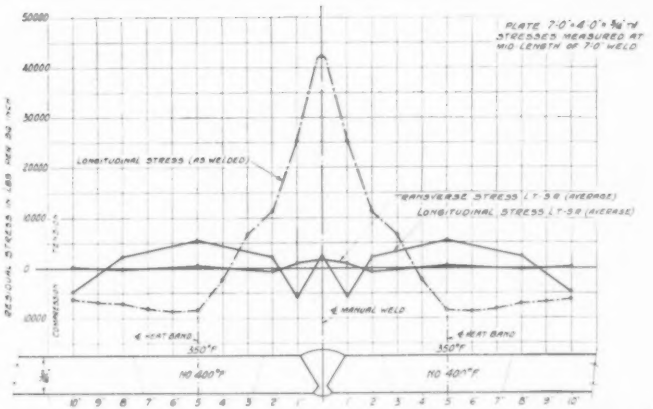


Fig. 3 Typical residual stresses after low-temperature stress relieving compared with as-welded stresses

are subjected to the highest stress from internal pressure are purposely put under initial residual compression.

Low-Temperature Stress Relieving

Two methods of stress relieving were used in this investigation. One was the common method of furnace stress relieving in which the whole weldment was heat treated to 1200° F. for 1 hr. This method alters the metallurgical structure and materially improves the weldment. The other method used was that known as low-temperature stress relieving[5] which has been used during the last three years on T-2 tankers, penstocks, large field-erected tanks[6] and pressure vessels;[7] all structures that cannot be put into a furnace. Low-temperature stress relieving consists of progressively heating bands on each side of the weld to about 350° F. Six-inch wide oxyacetylene torches are used for this work. The heating torches are followed by air-water cooling applied about 6 in. behind the advancing flames. The speed of application or travel of the machine is determined by the thickness of the welded plate. Figure 2 shows the low-temperature stress relieving of the welds on the deck of a T-2 tanker. Figure 3 shows the typical residual stresses after treatment in comparison with the as-welded residual stresses of a $^3/_4$-in. butt weld. For further information and details about this method, reference should be made to the papers and publications listed in the bibliography.

PRELIMINARY TESTS

Intersecting Welds with Reproducible Defects

The purpose of the preliminary test was to set up a reproducible defect in the form of a crack which is transverse to the high longitudinal residual stresses of a weld. Such a reproducible, purposely made, defect can readily be incorporated at a weld intersection. See the sketch in Fig 6. Test plates $^3/_4$ in. thick with intersecting transverse and longitudinal butt welds were made by welding four equal plate sections (beveled to 70° included angle) to produce a plate weldment approximately 36 in. wide by 30 in. long with the longitudinal weld running the length of the 30 in. side. The four beveled plates were assembled and tacked near the ends of the seams. A tack 2 in. long was then deposited in the transverse seam at the intersection with the longitudinal seam. This tack was purposely cracked by vibrating the assembly during deposition. This transverse crack was made $^5/_{16}$ in. deep and 2 in. long by making two welding passes in the above described manner. Where necessary, chipping and grinding were done to maintain these dimensions. Figure 4 shows this reproducible crack in a close-up view of a fractured test plate.

After the defect was made, the remaining portions of the transverse weld were finished before starting the longitudinal weld. In making the transverse weld, care was taken to leave the intersection of this weld with the longitudinal weld unwelded except for the original $^5/_{16}$-in. deep cracked tack. The longitudinal 30-in. long joint was welded last. Both welds were finished with $^1/_4$-in. diameter heavy mineral coated A.W.S. E-6020 welding electrodes following the root pass with $^5/_{32}$-in. rod.

In regard to the residual stresses at the intersection of welds in test plates of this type, it is important to note that published data[5, 6] show that the longitudinal and transverse residual stresses in the last weld made at intersecting butt welds are approximately equivalent to the residual stresses which might be developed in a single butt weld.

A total of six test assemblies of the type described were prepared by the same welder. All assemblies were made from the same plate material to eliminate any possible effect of variations in the plate composition. Two plates were tested as-welded, two after being low-temperature stress relieved, and two after being furnace stress relieved. The plates which were low-temperature stress relieved were treated

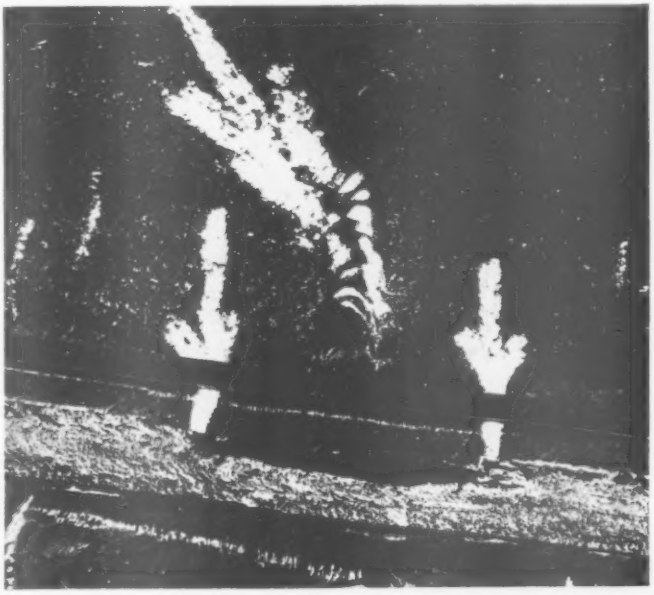


Fig. 4 Photograph of $^5/_{16}$-in. deep by 2-in. long weld crack defect at intersecting butt welds in preliminary bend tests

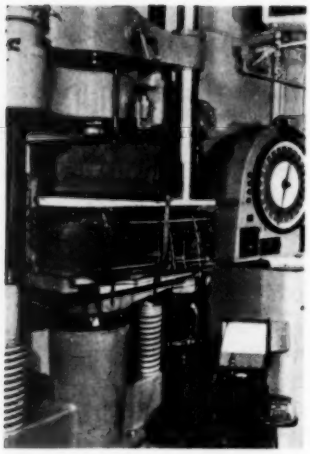


Fig. 5 Bend test of large, 36-in. wide, welded plate specimens with reproducible weld defects at center of span. Test span 23 in.

at a speed of 16.5 in. per minute in accordance with the prescribed procedure for this method of stress relieving. The furnace stress-relieved weldments were heated to 1200° F. for 1 hr. and allowed to cool slowly within the furnace to 400° F. before removal.

All six test assemblies were subjected to bending tests while maintained at −20° F. They were loaded as a simple flat beam with 23-in. span. The span was limited to 23-in. because of the physical limitations of the available testing equipment (a 120,000-lb. Baldwin-Southwark testing machine). A seal bead was applied to the bottom side of all welds and then the transverse welds in all test plates were ground flat on both sides to maintain full plate thickness through the weld. This grinding was necessary since the maximum bending moment was located at this weld and since further development of the transverse crack was expected in the direction of this weld. The longitudinal weld was also ground flat with the plate, but only for about 6 in. on each side of its intersection with the transverse weld.

The simulated transverse crack was set at the mid-point of the 23-in. span with the crack running parallel with the supports. In this arrangement, the bending stresses were parallel with and additive to the maximum longitudinal residual stresses acting across the transverse crack. The test plates were loaded with the root of the weld on the bottom of the plate. The bending load was applied as a uniformly distributed load across the 36 in. width of plate by means of a transverse loading beam at the mid-point of the span. The test setup is shown in Fig. 5.

The plates were cooled uniformly to the testing temperature of −20° F. before the initial load was applied and maintained at that temperature during the test. Both contact pyrometers and thermocouples were used constantly to be sure that the temperature remained at this value. The deflection of the plate under load was measured between the plate and the bottom platens of the hydraulic testing machine.

Table 1—Bend Test of Intersecting Welds with Defects Crack 5/16 x 2 In. Long at Intersection Weldment 30 x 36 In. Wide, Tested 23-In. Span at −20° F.

Test plate No.	*Elastic limit, psi.*	*Bending stress at fracture or maximum load, psi.*	*Deflection at maximum load, in.*	*Remarks*
		As-welded		
1A	...	10,000	0.05	Cracked 6 in.
1B	...	3,300	0.02	Cracked 6 in.
		Low-temperature stress relieved		
2A	58,000	82,000	0.75	Cracked across
2B	55,000	68,200	0.31	Cracked 12 in.
		Furnace stress relieved (1200° F.)		
3A	49,000	70,000*	2.25	No failure
3B	55,000	83,000*	2.05	No failure

*Computed stress at maximum applied load, test discontinued because of deflection limitations.

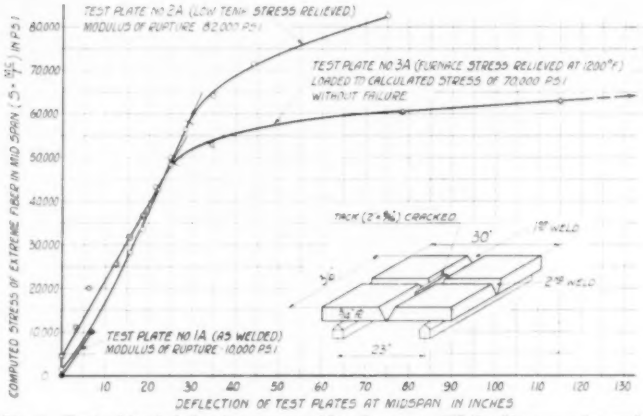

TEST PLATE NO 2A (LOW TEMP. STRESS RELIEVED)
MODULUS OF RUPTURE (82,000 PSI)
TEST PLATE NO 3A (FURNACE STRESS RELIEVED AT 1200°F)
LOADED TO CALCULATED STRESS OF 70,000 PSI
WITHOUT FAILURE
TACK (2 x 3/8") CRACKED
30"
1ST WELD
2ND WELD
5/8"
3/4"
23"
TEST PLATE NO 1A (AS WELDED)
MODULUS OF RUPTURE 10,000 PSI
COMPUTED STRESS OF EXTREME FIBER IN MID SPAN (5 x 36/4) IN P.S.I
DEFLECTION OF TEST PLATES AT MIDSPAN IN INCHES

Fig. 6 Typical load-deflection curves of bend test at −20° F. of intersecting welds with reproducible defects

Test Results of Intersecting Welds

Bend tests of as-welded—low-temperature stress-relieved—and furnace stress-relieved plates, all of which contained an intersecting weld with a reproducible defect, were carried out at −20° F. The results are given in Table 1 and typical load deflection curves of Plates 1A, 2A and 3A are shown in Fig. 6. The bending stresses or extreme fiber stresses were computed by the standard beam formula

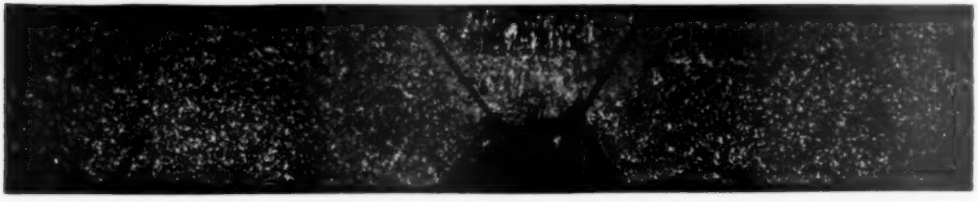


Fig. 7 Fracture through large, 3/16-in. deep, jeweler's saw-cut defect. Note: First and second bead cracked during welding, also back seal weld

Fig. 8 Fracture through small, 3/16-in. deep, jeweler's saw-cut defect. Note: First bead cracked during welding, back seal bead not cracked

Table 2—Chemical Composition

Carbon, %	0.24
Manganese, %	0.51
Silicon, %	0.056
Phosphorus, %	0.014
Sulphur, %	0.028
Chromium, %	0.084
Nickel, %	0.03
Copper, %	0.082
Nitrogen, %	0.003
Soluble aluminum, %	0.013
Insoluble aluminum, %	0.011

$s = M/(I/c)$ where M is the moment (a function of the load and span) and I/c the section modulus. This formula does not give the true extreme fiber stresses for loads producing stresses above the elastic limit but it is proportional to the load and comparable for test plates of the same size.

The results of these preliminary tests are of pointed interest. The weldments in the as-welded state failed in a brittle manner at surprisingly low stress values of 3000 to 10,000 psi. and with little or no deformation. The stress-relieved plates sustained loads far above the yield point with considerable deflection, with the low-temperature stress-relieved plates failing at 68,000 to 82,000 psi. bending stress. The furnace stress-relieved plates did not fail in these tests due to the deflection limitation of the testing equipment. The greater deflection of the furnace stress-relieved plates in attributable to the metallurgical improvement produced by this treatment which is well known to decrease the elastic limit and yield point and improve the ductility.

MAIN INVESTIGATION OF WELDS WITH REPRODUCIBLE DEFECTS

The preliminary tests, although informative, involved several features that were undesirable from the standpoint of a scientific investigation of the evaluation of the effect of residual stresses. It was difficult to prepare the specimens so that they would be flat when completed. Fortunately, we were surprisingly successful in producing a flat weldment. However, it was felt that any variation in procedure might produce undesirable warpage. Our main concern was that we were testing weld metal only. Remember that the cracked tack 3/16 in. deep by 2 in. long became a part of the transverse weld. As was expected, the failure did initiate and propagate through and along this transverse weld although the crack sometimes deviated out into the base metal, as noted in a few of the tests. The test therefore was fundamentally a test of weld metal and not a combination of weld and base plate as desired.

Table 3—Results of Tensile Tests, 0.505-In. Specimens

	Yield strength, psi.	*Tensile strength, psi.*	*Per cent elongation in 2 in.*	*Per cent reduction of area*
Longitudinal to rolling direction	40,000	65,500	37.0	61.6
	35,500	65,500	37.0	62.1
Transverse to rolling direction	36,500	66,000	33.5	51.4
	36,500	66,000	34.0	54.4

Table 4—Results of Charpy Impact Tests

Temp. of testing, ° C.	*Energy absorbed, ft.-lb.* Longitudinal	Transverse
	Charpy Vee Notch	
40 (104° F.)	41, 40	39, 37
25 (77° F.)	33, 18	24
0 (32° F.)	7	7
−20 (−4° F.)	4	5
−40 (−40° F.)	3	4
	Charpy Keyhole Notch	
40 (104° F.)	40, 37	31, 28
25 (77° F.)	35, 32	27
0 (32° F.)	26, 25	20
−20 (−4° F.)	4	5
−40 (−40° F.)	3	3

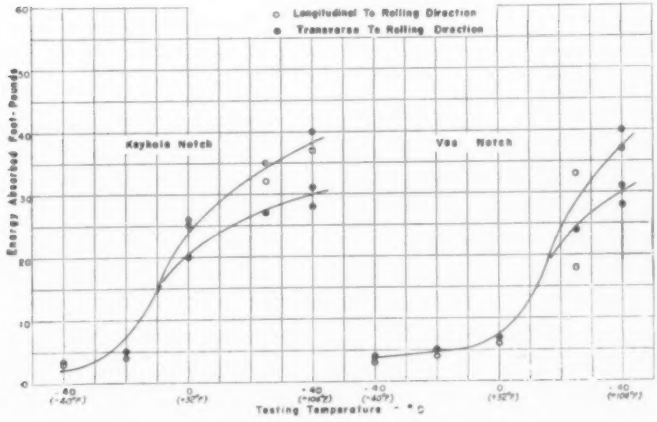


Fig. 9 Charpy impact test results of plate material

A weld is a complex structure in which the metal is heated to various temperatures and then cooled. The temperature varies from that of molten metal to that of the initial temperature of the plate. Messrs. Stout and McGeady[5] in their noteworthy investigation of the embrittlement of welded plates have shown that under external loading, cracking originates in the intergranular structure of the coarse grains in the weld-heated zone just under the fusion line of the weld. Bend specimens 3 in. wide were prepared with a bead deposited on the surface and then notched transversely. After the samples were subjected to various degrees of bending they were etched and the cracks were re-

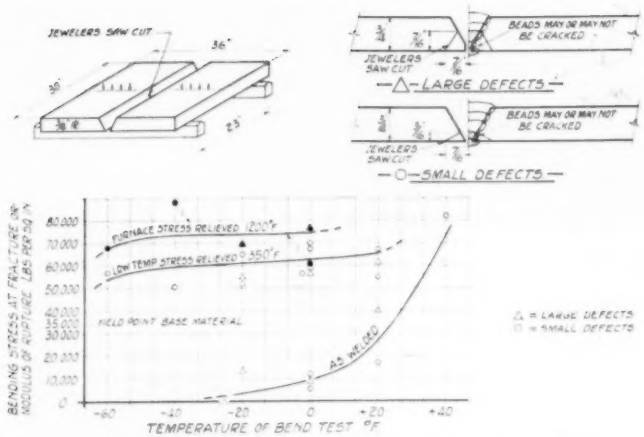


Fig. 10 Load carrying capacity in bending at various testing temperatures of welded plates with jeweler's saw-cut defect

vealed. These intergranular cracks appeared long before the steel specimens used reach their maximum load in bending. The Stout and McGeady investigations also showed that there appeared to be impairment in the heated-zone structure located beyond the coarse grains, because the resistance to propagation of the crack in the weld zone is strongly and adversely affected by the notch sensitivity of that steel structure which is heated within the critical range of the steel. Investigations by Messrs. Grossman and MacGregor[8] seem to indicate that there is also some impairment of the base metal well beyond the heat-affected zone, at least to the extent of raising the transition or embrittlement temperature of the base metal.

It seemed very desirable to develop a test specimen that would not be complicated by a transverse weld and would encompass all these critical zones.

Development of Notch or Stress Raiser

Several attempts were made to develop a suitable reproducible notch or stress raiser in a longitudinal weld before a satisfactory notch was developed. It was recalled that during the war in severe cold weather, quite a few transverse cracks found in plate weldments in the shipyards seemed to initiate from the sharp circular indentation left by plate lifting clamps when subsequent trimming of the plates happened to bring these indentations at edges that were butt welded. These sharp indentations acted as notches or stress raisers transverse to the longitudinal stresses in the weld. A jeweler's saw-cut was therefore tried in the bottom half of the beveled edge of a longitudinal butt weld as shown in Fig. 7, in an attempt to duplicate these fabrication failures. The first tests were made using a jeweler's saw-cut $^{7}/_{16}$ in. deep by $^{7}/_{16}$ in. wide, back from the root face of the bevel. Later, tests were made with the jeweler's saw-cut reduced to only $^{3}/_{16}$ in. depth (Fig. 8). Within these limits, the size of the cut did not seem to make much difference in the test results. A notch only $^{1}/_{8}$ in. deep was tried without success in an attempt to break weldments at atmospheric temperature below the yield point, but this was not thoroughly explored. In a bend test it is desirable to locate the notch or stress raiser as near as possible to the surface on the tension side of the plate where the imposed bending stresses are highest. However such a notch or stress raiser minimizes the possibility of setting up triaxial restraint with a stress raising component in the third dimension, that is, in the direction of thickness.

The $^{3}/_{16}$- and $^{7}/_{16}$-in. notches proved to be surprisingly severe. It was found after the specimens were tested that there had been transverse cracking of some of the beads, although no cracking was observed during the deposition and cooling of a bead deposit. Each bead was wire brushed and carefully examined, in many cases with magnetic powder, but no transverse cracks were found in any beads. It was evident that these transverse bead cracks had been produced by the stresses and strains of subsequent beads. In a few cases the back seal bead was found cracked after it was ground flush with the plate and tested with magnetic powder although no crack was noted when this bead was made. It did not appear that these transverse bead cracks had too much effect on the test results but they may have contributed to the scatter of results, particularly in the amount of deflection sustained by the plates before failure. All test plates were fractured and the extent of the cracked beads carefully noted and reported in the data. See Figs. 7 and 8 for typical fractures.

BASE METAL FOR LARGE PLATE WELDMENT

Some 26 large plate weldments approximately 36 in. wide by 30 in. long, having a longitudinal weld with a reproducible transverse saw-cut defect, were tested by bending. All were taken from the same $^{3}/_{4}$-in. thick large plate. Chemical analysis of the plate material is recorded in Table 2 and the physical properties in Tables 3 and 4. The Charpy impact tests including both Charpy vee notch and Charpy keyhole notch recorded in Table 4 are shown plotted in Fig. 9.

The composition of this plate indicates that the steel was semikilled and more or less typical of low-carbon structural steel used in ship and bridge construction. A deep-etch test on a small section of the plate gave further evidence that the steel was semikilled. The deep-etch test also indicated the direction of rolling.

The slow bend tests of notched 3-in. wide specimens with a welding bead deposited on the surface, which will be discussed later in detail, indicate the following embrittling temperatures. These are based on 1% lateral contraction (0.03 in. for 3-in. wide slow bend specimens but the criteria of the angle of bend indicates practically the same embrittling temperatures:

Prime plate, as-rolled	Lower than 70° C. (approximately −80° C. or −112° F.)

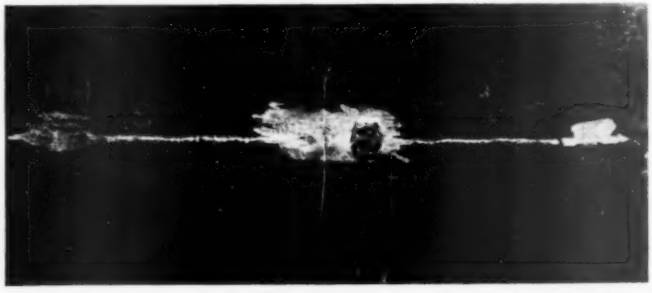


Fig. 11 Fracture 7 in. long in as-welded test plate at zero load. Plate broke at −25° F. while warming up to −20° F. for test

Table 5—Bend Test at Various Temperatures of Large Longitudinal Welded Plates with Reproducible Defects

Temperature of test, °F.	Specimen No.	Specimen Width, in.	Weld Bead Cracks: Depth saw cut, in.	Weld Bead Cracks: 1st Bead	Weld Bead Cracks: 2nd Bead	Weld Bead Cracks: Seal bead under side	Initial Fracture: Computed bending stress, psi.	Initial Fracture: Deflection, in.	Length initial crack, in.
			As-welded						
−25	1C*	36	7/16	Yes	Yes		0	0	7
−20	1AA	35.25	7/16				13,500	0.084	5 3/4
0	1BB	35.25	7/16	Yes	No	No	8,700	0.044	9
0	1DD	35.75	3/16+	Yes	Yes	Yes	6,000	0.062	8
0	1EE	34.88	3/16+	Yes	No	Yes	11,900	0.078	5
+20	1CC	35.19	7/16	Yes	Yes	Yes	39,600	0.193	6
+20	1FF	31.75	3/16	Yes	Part	No	16,800	0.090	5
+40	1GG	26.44	3/16	No	No	No	82,200	1.72	2 1/2
			Low-temperature stress relieved						
−60	2JJ	26.44	3/16	Yes	Yes	No	56,500	0.325	Complete
−40	2HHb	26.81	3/16	Yes	Yes	Yes	50,600	0.238	Complete
−20	2GG	32.88	3/16	Yes	Yes	No	65,000	0.460	Complete
−20	2C*	34.88	7/16	Yes	Yes		53,700	0.281	16
−20	2BB	35.31	3/16				52,800	0.277	21
0	2AA	35.31	7/16	Yes	No	No	59,000	0.360	3 1/2
0	2CC	35	7/16	Yes	No	No	56,700	0.330	3 1/2
0	2DDb	34.63	3/16+	No	No	No	69,800	0.850	4
0	2EE	35.81	3/16	Yes	No	No	56,300	0.307	2
0	2HHa	30.88	3/16	Yes	No	No	67,800	0.575	5
+20	2DDa	35.25	7/16	Yes	Yes	Yes	60,500	0.590	3
+20	2FF	31.44	3/16				55,000	0.360	2
+20	2II	26.64	3/16	Yes	Yes	Yes	67,000	0.610	4
			Furnace stress relieved 1200° F.						
−60	3FF	26.44	3/16	Yes	Part	Yes	66,600	0.630	Complete
−40	3EE	25.88	3/16	Yes	Yes	No	88,000	2.84	Complete
−20	3C*	35.81	7/16	Yes	Yes		69,000	1.31	24
0	3AA	35.19	7/16	No	No	No	76,700	1.89	14 1/2
0	3BB	35.44	3/16	Yes	Yes	Yes	60,500	0.60	2 3/8

* NOTE: Initial test plate available at Newark Laboratory; all other tests made from one large 3/4-in. plate. All bend tests made on 23-in. span.

As-welded ..... +15° C. (+59° F.)
Welded and furnace stress relieved ..... −50° C. (−58° F.)

From these data it appears, as found by other investigators, that most steels have their embrittlement temperature raised by welding. Furthermore furnace stress-relieving treatment at 1200° F. greatly benefits the welded specimens and lowers the embrittling temperature nearly to that of the prime plate.

WELDING AND TESTING OF LARGE PLATE WELDMENTS

All the large plate weldments containing the reproducible saw-cut defect were welded by the same welder using A.W.S. E-6020 welding electrodes. Care was exercised to standardize the procedure of welding. The weldments were allowed to cool to room temperature (70 to 80° F.) after each pass. All passes were started at one end of the seam and continued to the other. It is well known that preheating has a beneficial effect. With small weldments the heat of welding itself produces some preheating and this one factor when not controlled has vitiated the results of many investigations. The procedure used therefore represented field conditions. In making long field welds there is little preheating from the welding itself and welding must be stopped for change in shifts, inclement weather or other causes.

The welded plates were tested by bending at various testing temperatures from −60 to +40° F. Some of the plates were tested as-welded, some after low-temperature stress relieving and some after furnace stress relieving. Care was taken to keep the temperature constant and uniform during the bend test. Checks were made at various points with both contact pyrometers and thermocouples. Powdered dry ice was used as the cooling medium.

All the test plates were subjected to bending tests as a simple flat beam on 23-in. span in a 120,000-lb. Baldwin-Southwark testing machine. The longitudinal weld in all test plates was ground flat on both sides (a back seal bead was applied to the bottom side of all welds) to maintain the 3/4-in. plate thickness through the weld at the mid-span. The transverse jeweler's saw cut was set at the mid-

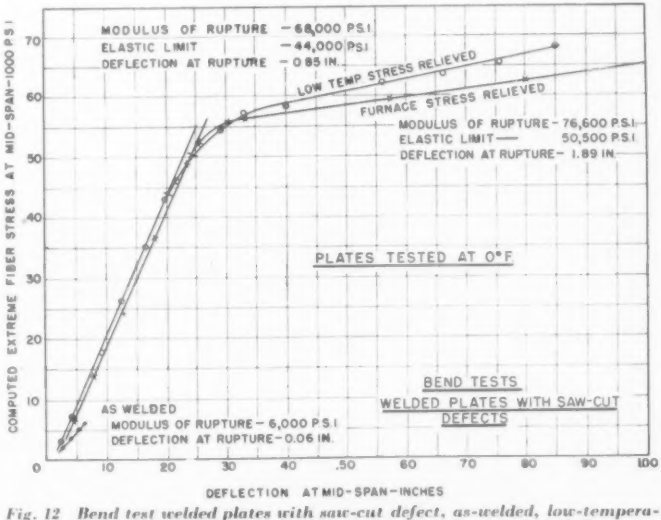


Fig. 12 Bend test welded plates with saw-cut defect, as-welded, low-temperature stress relieved and furnace stress relieved; tested at 0° F.

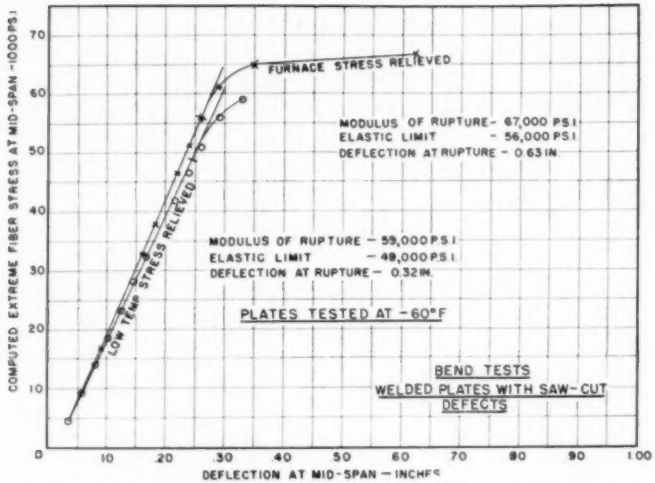

COMPUTED EXTREME FIBER STRESS AT MID-SPAN - 1000 PSI
DEFLECTION AT MID-SPAN - INCHES
FURNACE STRESS RELIEVED
MODULUS OF RUPTURE - 67,000 PSI
ELASTIC LIMIT - 56,000 PSI
DEFLECTION AT RUPTURE - 0.63 IN.
LOW TEMP STRESS RELIEVED
MODULUS OF RUPTURE - 59,000 PSI
ELASTIC LIMIT - 49,000 PSI
DEFLECTION AT RUPTURE - 0.32 IN.
PLATES TESTED AT -60°F
BEND TESTS
WELDED PLATES WITH SAW-CUT DEFECTS

Fig. 13 Bend test welded plates with saw-cut defect: tested at −60° F.

point of the 23-in. span with the simulated defect running parallel with the supports. In this arrangement, the applied bending stresses were parallel with and additive to the maximum longitudinal residual welding stresses and at right angles across the simulated defect. The test setup is shown in Fig. 5.

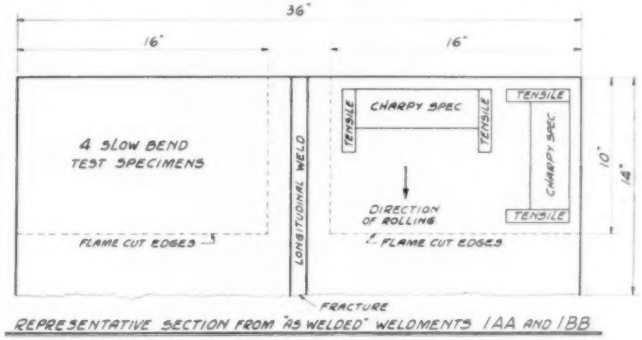
DISCUSSION OF RESULTS OF BEND TEST OF WELDS WITH REPRODUCIBLE DEFECTS

The results of all the bend tests of large weldments—as-welded, low-temperature stress relieved and furnace stress relieved—tested at various temperatures, are given in Table 5 and shown plotted in Figs. 10, 12 and 13. The test results are surprisingly informative. All the as-welded specimens tested at low atmospheric temperatures (−20 to +20° F.) failed at very low stress values of 0 to 17,000 psi. These plates failed in a very brittle manner with little or no deflection. In fact, one specimen (1C) failed at zero load. It was intended to test this specimen at −20° F. but the temperature of the plate got down to −25° F. While we were waiting for the steel to warm up to −20° F. before starting the test, the specimen cracked for 7 in. across the tension zone of the longitudinal residual welding stresses as shown in Fig. 11. This failure without load could be caused only by residual welding stresses. It is believed that this is the first time that plate failures similar to those that have occurred in welded merchant ships, in large weldments in shipyards and also in large pressure vessels and tanks, have been quantitatively reproduced under controlled laboratory conditions.

It is to be noted from Table 5 and the Curve in Fig. 10 that it was only when the test temperature was raised to +40° F. would the as-welded specimens sustain loads above the yield point of the material. In contrast, all the stress-relieved weldments, whether low-temperature stress relieved at 350° F. or furnace stress relieved at 1200° F., sustained loads well above the yield point of the plate, with considerable deflection and ductility, even at temperatures as low as −60° F. The furnace stress-relieved weldments sustained slightly higher loads and exhibited greater ductility as indicated by slightly greater deflection. The results were somewhat scattered with the furnace stress-relieved weldments and this may have been due to the cracks which formed in some of the weld beads adjacent to the saw cuts.

This data shows that the transition or embrittling temperature, as manifested by the criteria of load carrying capacity and deflection, was reduced at least 100° F. from +40 to −60° F. by stress relieving. This is in surprisingly close agreement with the slow bend notch tests of the prime plate. These tests showed that after being impaired by welding a surface bead, with resulting raising of the embrittlement temperature from −110 to +60° F., furnace stress-relieving treatment reduced the embrittlement temperature to −60° F.

Such a lowering of embrittlement temperature and improvement of mechanical properties by stress relieving is of utmost importance. When the embrittlement temperature is high and within the range of atmospheric temperatures, a notch or weld defect may lead to disaster. However, stress relieving pushes the embrittle-



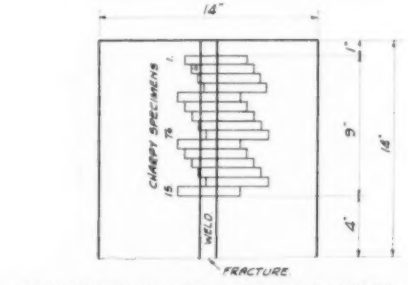


Fig. 14 Slow bend and impact specimens cut from large, 36-in. wide weldments

ment temperature down far below normally experienced atmospheric temperatures. All the stress-relieved weldments, even those with the most severe notches, carried loads corresponding to stresses well above the yield point even at −60° F. temperature.

Stress relieving practically gives assurance against premature brittle failure of welds due to minor defects. Engineering structures are generally so designed that stresses will be well below the elastic limit of the steel, and rarely, except at stress raises or points of stress concentration, do stresses reach the elastic limit. When stress-relieving treatment makes weldments capable of sustaining applied loads to well above the yield point, there can be local yielding at points of stress concentration. This local yielding should redistribute the high peak stresses at defects, cracks, and minor discontinuities, and consequently welded plate structures containing normal defects should not fail prematurely with brittle type fractures when subjected to operating stresses even at low atmospheric temperature.

In view of the constructive results obtained from tests of the large weldments, it was felt that correlation with the results obtained from slow bend tests of small specimens, patterned after those used in weldability studies by other investigators, would be desirable.

SLOW BEND TEST

Four 14- by 36-in. steel sections of the as-welded plates that failed at low loads were sent to Union Carbide and Carbon Research Laboratories for further testing. Two 10- by 16-in. sections were flamecut from each of the four larger sections in order to eliminate the welds, the areas near the weld and also the zones which had been stressed during testing as indicated by cracks in the scale. The specimens for slow bend testing, as well as the tensile and Charpy impact specimens, were secured from the sections thus prepared, as shown in Fig. 14.

The 10-in. long slow bend specimens were prepared with a width of 3 ± 0.01 in., the 0.05-in. deep, 0.01-in. radius notch being placed transverse to the rolling direction of the plate. All welded specimens were longitudinally bead-welded with an automatic machine using the following technique:

Single pass
175 amp., 26 v., 6 in. per minute
Open-circuit voltage, 77–80 v.
Rod, A.W.S. E-6010 (5/16 in.)

The furnace-stress-relieving treatment applied to some of the welded specimens was practically the same as that recommended in A.W.S. specifications, the specimens being heated at the rate of 175° C. per hour to 650° C., where they were held for 1 hr. before cooling at the same rate of 175° C. per hour. All specimens were bent on a 6" -in. span, using a 1/2-in. radius ram. Load-deflection diagrams were automatically recorded during the testing of each specimen, the measurements of the energy absorbed, ratio of proportional limit to the maximum load and type of fracture being taken therefrom.

RESULTS OF SLOW BEND TESTS

The results of slow bend tests of notched specimens are plotted in Figs. 15 and 16. The data indicate the following embrittling temperatures, based on 1% lateral contraction (0.03 in.) for the three types of specimens tested.

Prime plate, as-rolled . . . . . lower than −70° C. (approximately −80° C. = −112° F.)
As-welded . . . . . +15° C. = +59° F.
Welded and furnace stress relieved . . −50° C. = −58° F.

From these data it appeared that the stress-relieving treatment greatly benefited the welded specimens.

STUDY OF METALLURGICAL EFFECT OF STRESS RELIEVING

Because of the beneficial effect of stress relieving, both furnace and low temper-

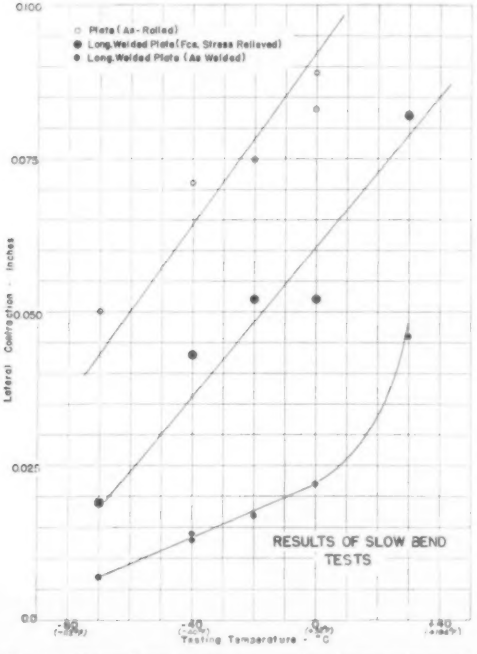


Fig. 15 Lateral contraction vs. testing temperatures of slow bend test. Specimens 3 in. wide with longitudinal welded bead, transverse notch

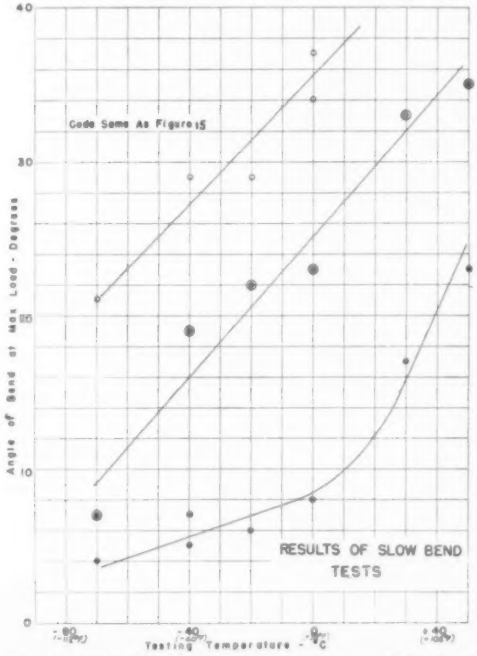


Fig. 16 Angle of bend vs. testing temperature of slow bend test. Specimens 3 in. wide with longitudinal welded bead, transverse notch

ture, an attempt was made to study the metallurgical effect of stress relieving.

One-half of each of the large weldments as-welded, low-temperature stress relieved and furnace stress relieved were used in the preparation of Charpy impact specimens to be notched at various points within and near the weld. The locations of these Charpy specimens with respect to the weld are also shown in Fig. 14.

The special Charpy specimens (transverse to the weld and to the rolling direction of the plate) were used for studying the areas within and near the welds on the large previously tested weldments. In preparing these specimens they were first shaped to the proper cross section and then etched to bring out the fusion line of the weld. The measurements locating the root of the vee notch were then made along one side of the specimens at the level of the root of the notch. The notch was located on the face representing the surface of the plate which contained the final welding pass. It should be noted that because of slight variation in the weld contour, the material at the root of the notch was probably not the same throughout in all specimens. However, this condition should not detract from the results obtained, in view of the fact that each specimen still represented a certain zone in each of the large weldments.

RESULTS OF CHARPY IMPACT TESTS OF AREAS WITHIN AND NEAR THE WELD

The results obtained from tests of Charpy vee notch specimens in which the notches were placed at points within the weld and weld heat-affected zones of large weldments are shown graphically in Figs. 17 and 18. In the graphs, each of the three types of weldments is represented by solid lines, the dotted line representing the amount of energy absorbed by the plate at the particular temperature of testing.

A study of Fig. 17, which shows the results of tests at +12° C. or +53° F. (the temperature at which the plate absorbed 75 ft.-lb.), indicates that the entire heat-affected area of the as-welded weldment contained metal displaying a greater tendency toward brittleness than the plate metal. However, definite improvement in the brittle behavior of the stress-relieved material was indicated. A major portion of the heat-affected area adjacent to the weld and the weld metal displayed properties superior to the plate metal. The tests at room temperature, shown in Fig. 18, appear to further demonstrate the superior behavior of the stress-relieved weldments.

The results are somewhat scattered and the tests were limited in number so a definite conclusion is not justified. However, further investigation of the effect of stress relieving by such a study of the weld and adjacent areas seems highly desirable.

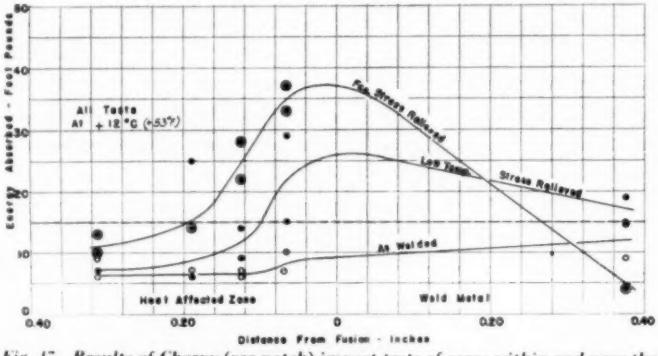


Fig. 17 Results of Charpy (vee notch) impact tests of areas within and near the longitudinal weld on large weldments at +12° C. (+53° F.)

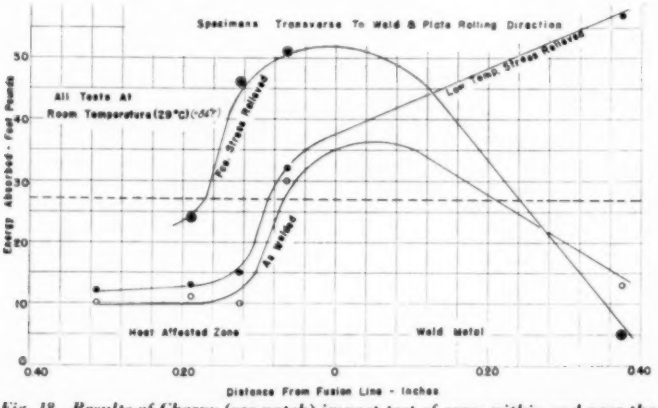

Specimens Transverse To Weld & Plate Rolling Direction
All Tests At Room Temperature (29°C) (84°F)
Fur. Stress Relieved
Low Temp. Stress Relieved
As Welded
Heat Affected Zone
Weld Metal
Energy Absorbed - Foot Pounds
Distance From Fusion Line - Inches

Fig. 18 Results of Charpy (vee notch) impact test of areas within and near the longitudinal weld on large weldments at room temperature, 29° C. (+84° F.)

SUMMARY AND CONCLUSIONS

1. Any attempt to evaluate the effect of residual welding stresses is admittedly difficult and many investigations have led to controversial interpretations. It is believed some of the reasons why numerous investigations have not been more fruitful in correlating laboratory results with known field conditions and service experience are (*a*) the small laboratory specimens, (*b*) the extreme difficulty of isolating the effect of residual welding stresses from other metallurgical factors and (*c*) the necessity of testing sound welds above the yield point to produce failure at atmospheric temperatures.

2. In this investigation an attempt was made to evaluate the effect of residual stresses upon the mechanical properties of welded plates by using relatively wide (approximately 3 ft. square) weldments in which the welding conditions and stresses were nearly comparable to field conditions, and setting up in the welds when made, reproducible defects as notches and triaxial stress raisers. In a few preliminary tests, cracks of controlled dimensions were set up at weld intersections. Tests of these weldments in bending at −20° F. developed fractures at 3000 to 10,000 psi. when tested in the as-welded state. In contrast, the welded plate specimens that were stress relieved by the low temperature method at 350° F. or furnace treated at 1200° F. sustained loads well above the yield point of the material.

3. In a more comprehensive series of tests, a large number of bend tests were made at various temperatures (from −60° to +40° F.) on 3 ft. wide specimens all cut from one large plate. These contained a longitudinal weld with a reproducible transverse defect, made as a small cut with a jewelers saw, both with or without accompanying cracked beads. The as-welded plates tested at low atmospheric temperatures (−20 to +20° F.) failed in a brittle manner with little or no deflection, at bending stresses from 0 to less than 17,000 psi. One specimen failed at zero load through the residual tension stressed zone when inadvertently cooled to −25° F. It is believed this is the first time that failures, similar to

those that have occurred in welded merchant ships and large tanks during fabrication and service have been quantitatively reproduced under controlled laboratory conditions.

4. The results indicate that only at temperatures above +40° F. would the as-welded specimens sustain bending loads producing stresses above the yield point, whereas all the low-temperature stress relieved and furnace stress-relieved plates sustained imposed load stresses well above the yield point at temperatures down to at least −60° F. The transition or embrittlement temperature in these plate weldments as manifested by the criteria of load carrying capacity and deflection was improved, i.e., lowered more than 100° F. (from +40 to −60° F.), by stress relieving.

5. Slow bend tests, transition temperature determination and physical tests of the plate material are reported to permit correlation of the steel used with that used in other investigations. Charpy impact tests showed that, in the as-welded state areas within and near the weld were more brittle than the plate metal. Definite improvement of the stress-relieved material was indicated in the weld metal, and a major portion of the heat-affected area adjacent to the weld.

6. The furnace stress-relieved plates were only about 10 to 15% better than low-temperature stress-relieved weldments as measured by load carrying capacity and were somewhat more ductile as determined by deflection.

7. The data indicates that either low-temperature stress relieving or furnace stress relieving gives considerable assurance against premature failure.

ACKNOWLEDGMENTS

I wish to express appreciation to H. V. Inskeep, W. B. Sharav and others of the Development Division of The Linde Air Products Co. for their help and assistance in this investigation, and to Arthur R. Lytle, W. J. Goodwin and others of the Union Carbide and Carbon Research Laboratories, Inc., for the chemical analysis, slow bend and impact tests.

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Discussion by Finn Jonassen

The influence of internal stresses resulting from the welding operation upon the fracture of welded structures is not known. Recent studies bearing on the structural failures of welded ships have led to the conclusion that these stresses are not major factors in causing such fractures.[1]

This conclusion does, however, admit of the possibility that under certain conditions internal or residual welding stresses may influence fracture. Continued interest is therefore manifested in research investigations that bear on the subject, particularly those presenting experimental information on the effect of residual stresses on structural behavior. Mr. Greene's paper falls into this category and therefore demands our serious attention.

The low-temperature stress-relieving procedure involves stretching the weld plastically. The tensile force causing this plastic flow is produced by differential heating whereby the weld is held at about 150° F. and the compressive zones on each side of the weld (see References 5 and 7 of the paper) are heated to about 350° F. While the amount of general strain necessary to produce stress relief is small, the amount of plastic flow near the mechanical notch (jeweler's sawcut) as used in this investigation may be sufficient to cause a significant reduction in the severity of the stress raiser. In addition, it is noted that this straining occured at a temperature (about 150° F.) when the steel and weld metal are notch tough, i.e., the material can flow readily without cracking and therefore no new notches are introduced. Thus the improvement resulting from the low-temperature stress-relieving treatment, which the author has attributed to stress relief may be due to a reduction in the notch acuity, thereby improving the low-temperature performance of the specimen.

It would be of great interest to study further, by means of this specimen, the possible effects of residual welding stresses on fracture when the welds are made at various preheat temperatures. Here metallurgical changes will result which will undoubtedly improve structural performance relative to that of as-welded specimens. The residual stress intensity in specimens welded with preheat will closely approach that in identical specimens but welded without preheat.

Earlier tests[2] involving a specimen (batch corner) that had a severe notch and a high degree of restraint did not show differences in structural performance between specimens welded with 400° F. preheat (containing high residual stresses) and an identical specimen furnace stress relieved at 1000° F. The magnitude of the residual stresses in the latter specimen was, of course, greatly reduced.

As indicated in Figs. 17 and 18, there appears to be improvements in the V-notch Charpy impact characteristics of weld and plate material from specimens that had been subjected to the stress-relieving treatments discussed by the author. The effects of furnace stress relief are well known and the results are as expected. It is difficult, however, to understand why there should be improvements in the material subjected to the low-temperature stress-relieving treatment over that in the as-welded condition. The impact specimens from the as-welded plate are, of course, also stress relieved through the subdivision necessary to produce the specimens. It is suggested that the scatter is great and that these apparent differences therefore result from the limited number of tests made.

Mr. Greene must be commended for the work reported in this paper on the recurring question of the effect of residual stresses on the mechanical performance of welded structures. Continued effort must be made to resolve this perplexing problem.

Finn Jonassen is Technical Director, Committee on Ship Steel, National Research Council, Washington, D. C.

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Discussion by E. M. MacCutcheon

Mr. Greene's paper presents the results of a very important series of tests. The author has devised something new in the form of a notched specimen. The specimens described in this paper contain real fabrication notches. Therefore, the results of the tests are absolute. Other notched-specimen tests involve notches which must be classified as "suitable for comparison" or "typically severe." The notch used in Mr.

Greene's test, however, is a real crack similar to those resulting from a workmanship defect or poor weldability. Only one equally realistic test comes to mind. This is the extremely expensive hatch corner facsimile used in a series of tests at the University of California.[1]

There are two other important features to this test which have not been sufficiently emphasized in the paper. First, it should be noted that a real temperature transition occurs on the basis of nominal stress, and second that low values of nominal stress occurred although the specimens involved no complicated over-all geometry. Most important of all, however, Mr. Greene has shown, for the first time, that a real improvement occurs in the performance of a welded structure when it has been treated by the so-called low-temperature, stress-relieving process. The number of large-scale tests he has used and the consistency of the results strengthen the findings so that there is little room for dispute.

Although it does not appear possible to dispute the findings, I am constrained to disagree with Mr. Greene's interpretation of the data. He has attributed the beneficial effect of the low-temperature stress-relieving method to the fact that it relieves the stresses. That this method relieves the stress cannot be disputed. Mr. Greene has adequately demonstrated this phenomenon with previous tests.[2] On the other hand, to assume that the improved structural performance results entirely from the stress relief is fallacious logic. On recent tests with sharply notched steel tensile specimens it was found that a slight prestrain occurring above the transition temperature had the effect of changing the specimen so that the resistance to the occurrence of brittle performance and cleavage fracture in subsequent testing at lower temperatures was greatly increased. In other words, if a series of notch bars is prestrained at a temperature above the transition subsequent tests on the same bars will show a substantial reduction in the transition temperature as compared to a transition temperature obtained on similar bars which have not been prestrained. During the so-called stress-relieving process the temperature ranges from 150° F. in the weld to 350° in the adjacent base metal. The prestraining which removes the locked-in stresses occurs under temperature conditions which are conducive to plastic flow. As already demonstrated on notched steel bars a lowering of the transition temperature in subsequent tests can be expected from this effect.

Low preheat temperatures and postheat temperatures bring about beneficial changes which are a function of the material and the temperature used. Previous tests have shown that temperatures between 150 and 350° F.[3] produce measurable improvements in the structural performance. Mr. Greene shows in Figs. 17 and 18 that the Charpy impact resistance of steel removed from the plate and weld was increased when the low-temperature stress relieving was applied. These Charpy bars had notches parallel to the direction of the high residual welding stress. Furthermore, tests have shown that they are too small to include over-all residual stresses of any magnitude. For this reason some of the improvement in performance must be attributed to a change which can be classified broadly as metallurgical, i.e., it is something related to chemistry, grain structure, gas content or intercrystalline stresses.

One of the specimens prepared for this investigation failed before the external load was applied. This failure reminds us of the many fractures which occurred in the ship hulls while they were under construction. It is clear that locked-in stresses play an important part in such failures. On the other hand, welded specimens prepared with a 400° F. preheat exhibit a remarkably improved structural performance in spite of the fact that locked-in stresses remain practically in full force.[3] The importance of the part played by locked-in stresses is one of degree and involves the relative contributions of the various parameters toward the occurrence of cracks.

The above discussion may be summarized by saying that there are at least three changes resulting from the application of the low-temperature stress-relieving process. First, it relieves the stresses; second, it rounds the notches; third, it improves the metallurgy. It is not fair to attribute the general improvement in structural performance to stress relief without giving recognition to other factors. The other two factors mentioned are confirmed benefactors. The relative contribution of locked-in stresses is an open question.

I believe that another real contribution to the advancement of our knowledge could be made by adding two series of tests to the program commenced by Mr. Greene. First, a series of specimens prestrained at 150 to 200° in a tensile machine and then tested at lower temperature to obtain a transition. Second, a series of specimens welded with 400° preheat and then tested to obtain a transition curve.

The above discussions should not be taken to imply that Mr. Greene has failed to achieve his objective. He was interested in showing that the so-called low-temperature, stress-relieving process brought about an improvement in the performance of the structure. He has succeeded in achieving his objective. The matter of explaining the improvement is a separate question the answer to which could add substantially to our general understanding of this problem.

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Stress Analysis of a Hortonsphere

Strain gage survey around the supports of a 48-foot diameter Hortonsphere. Present design stress allowances prove adequate

by L. P. Zick and C. E. Carlson

INTRODUCTION

THE purpose of this investigation was to determine the action of the column-to-shell connections of a 48-ft. diameter Hortonsphere supported on eight tubular columns. Under liquid load the complex stress distribution in this region has not yet been solved by theoretical analysis; therefore, electric strain gage measurements were made on a new commercial vessel to determine the existing stresses.

A secondary purpose was to prove or disprove the strain gage technique reported in this paper.

A 51-ft. diameter Hortonsphere supported on ten tubular columns and designed for 75 psi pressure was previously investigated and the stresses were found to be within the allowable value. However, most of the gages placed on the inside surface of this vessel were lost during the test; therefore the stresses at these points were not obtained. Further, bending was indicated in the shell at the edge of the column and it was felt that this would become more serious on thinner shells and when the span between posts increased.

The 48-ft. diameter Hortonsphere shown in Fig. 1 was built for the Cities Service Oil Co., at East Chicago, Ind., by the Chicago Bridge & Iron Co. It was designed to store 48 lb./ft.^{3} liquid under 60 psi working pressure, in accordance with the A.P.I.-A.S.M.E. Code for Unfired Pressure Vessels. The general dimensions and plate thicknesses are shown on the drawings.

The Cities Service Oil Co. and the Chicago Bridge & Iron Co. erection crew, headed by foreman Sid Stanley, cooperated with the authors in conducting this investigation.

GAGE LOCATIONS

Drawing 1 gives the locations of all the SR-4 strain gages. Two single gages, type A3, were installed on radially opposite sides of each column. These were used to determine the respective column loads. Delta rosette gages, type AR4-1, were installed on the inside and outside surfaces of the shell at points numbered from 1 to 29, inclusive. Similar gages were installed on the inside surface only at points 30, 31 and 32 since the outside surfaces were covered by the column.

Fig. 1 View of 48-ft. diameter Hortonsphere

All but seven of these points were placed on the shell around column 1 to investigate as fully as possible the action of the column-to-shell connection. Their locations are shown in Fig. 2 and on drawings 2, 3 and 4. The other seven points were located near the remaining 7 columns, each similarly located with reference to its column. These were used to indicate that the action of all the columns was similar.

Four delta rosette gages and two single gages similar to the active gages were installed on steel plates 9 x 9 x $\frac{5}{16}$ in. and were designated as dummy (unstressed)

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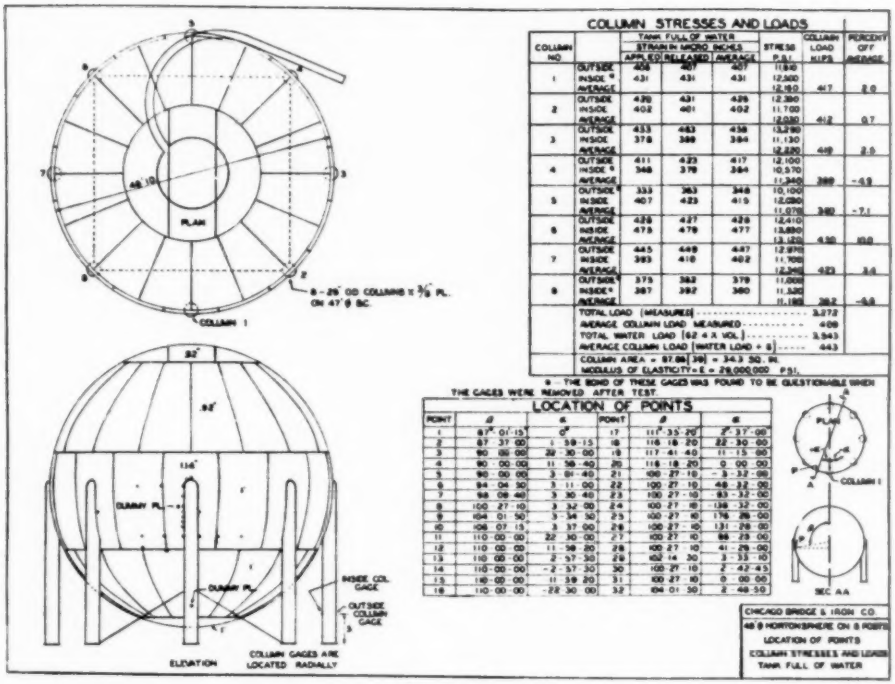


COLUMN STRESSES AND LOADS

TANK FULL OF WATER

COLUMN NO.		STRAIN IN MICRO INCHES APPLIED	STRAIN IN MICRO INCHES RELEASED	STRAIN IN MICRO INCHES AVERAGE	STRESS P.S.I.	COLUMN LOAD KIPS	PERCENT OFF AVERAGE
1	OUTSIDE	426	427	427	11,840		
	INSIDE *	431	431	431	12,300		
	AVERAGE				12,150	417	2.0
2	OUTSIDE	430	431	430	12,280		
	INSIDE	402	401	402	11,700		
	AVERAGE				12,030	412	0.7
3	OUTSIDE	433	433	433	13,280		
	INSIDE	378	388	384	11,130		
	AVERAGE				12,230	419	2.0
4	OUTSIDE	411	423	417	12,100		
	INSIDE *	348	378	364	10,570		
	AVERAGE				11,340	388	-4.9
5	OUTSIDE *	333	353	343	10,100		
	INSIDE	407	423	415	12,080		
	AVERAGE				11,090	380	-7.1
6	OUTSIDE	438	437	438	12,410		
	INSIDE	478	478	477	13,880		
	AVERAGE				13,120	450	10.0
7	OUTSIDE	445	449	447	12,970		
	INSIDE	393	418	402	11,700		
	AVERAGE				12,340	423	3.6
8	OUTSIDE *	375	383	379	11,000		
	INSIDE *	387	392	380	11,530		
	AVERAGE				11,265	386	-5.0
	TOTAL LOAD (MEASURED)					3,272	
	AVERAGE COLUMN LOAD MEASURED					409	
	TOTAL WATER LOAD (62.4 X VOL.)					3,543	
	AVERAGE COLUMN LOAD (WATER LOAD ÷ 8)					443	

COLUMN AREA = 87.86 (26) = 34.3 SQ. IN.
MODULUS OF ELASTICITY = E = 29,000,000 PSI.

* THE BOND OF THESE GAGES WAS FOUND TO BE QUESTIONABLE WHEN THE GAGES WERE REMOVED AFTER TEST.

LOCATION OF POINTS

POINT	ϕ	θ	POINT	ϕ	θ
1	87° 01'-15"	0°	17	111° 35'-20"	7° 37'-00"
2	87 37-00	1 39-15	18	116 18-20	22 30-00
3	90 00-00	28 30-00	19	117 41-40	11 15-00
4	90 00-00	11 56-40	20	116 18-20	0 00-00
5	90 00-00	3 01-40	21	100 27-10	- 3 32-00
6	94 04-30	3 11-00	22	100 27-10	46 32-00
7	98 08-40	3 30-40	23	100 27-10	83 32-00
8	100 27-10	3 32-00	24	100 27-10	138 32-00
9	104 01-50	3 34-50	25	100 27-10	176 28-00
10	106 07-15	3 37-00	26	100 27-10	131 28-00
11	110 00-00	22 30-00	27	100 27-10	88 28-00
12	110 00-00	11 56-20	28	100 27-10	41 28-00
13	110 00-00	2 57-30	29	102 14-30	3 33-10
14	110-00-00	-2 57-30	30	100 27-10	2 42-45
15	110-00-00	11 59-20	31	100 27-10	0 00-00
16	110-00-00	-22 30-00	32	104 01-50	2 48-50

Drawing 1

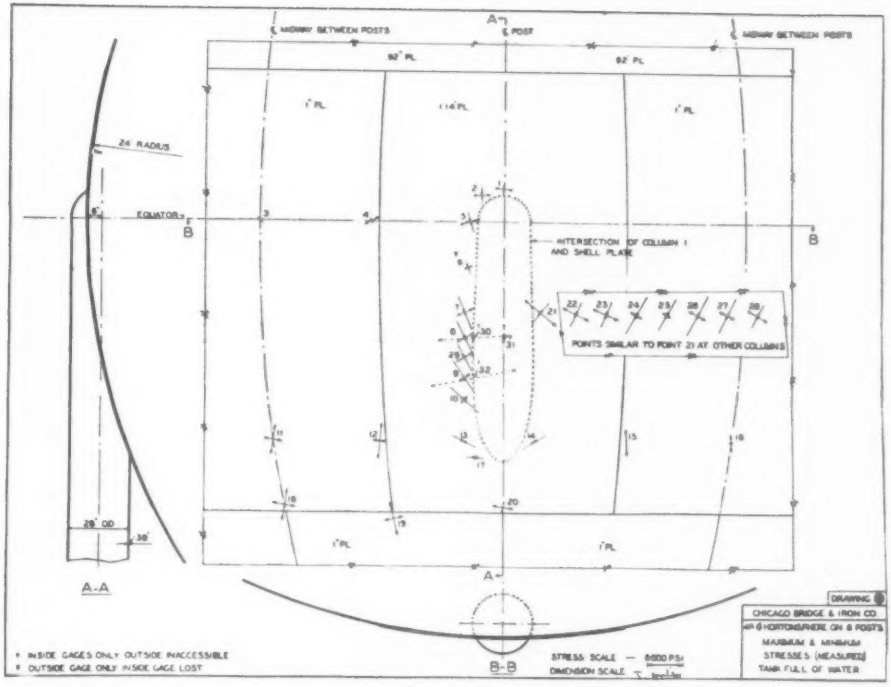
gages I to VI, respectively. Dummy plates I and II were hung on single bolts attached to the outside of the shell near columns 1 and 5, respectively, and one of these was used when reading the outside gages. Dummies III and IV were hung inside the tank opposite dummies I and II and one of these was used when reading the inside gages. Dummy plates V and VI were hung on single bolts attached to columns 1 and 5, respectively, and one of these was used when reading the column gages.

Fig. 2 View showing gages around column No. 1

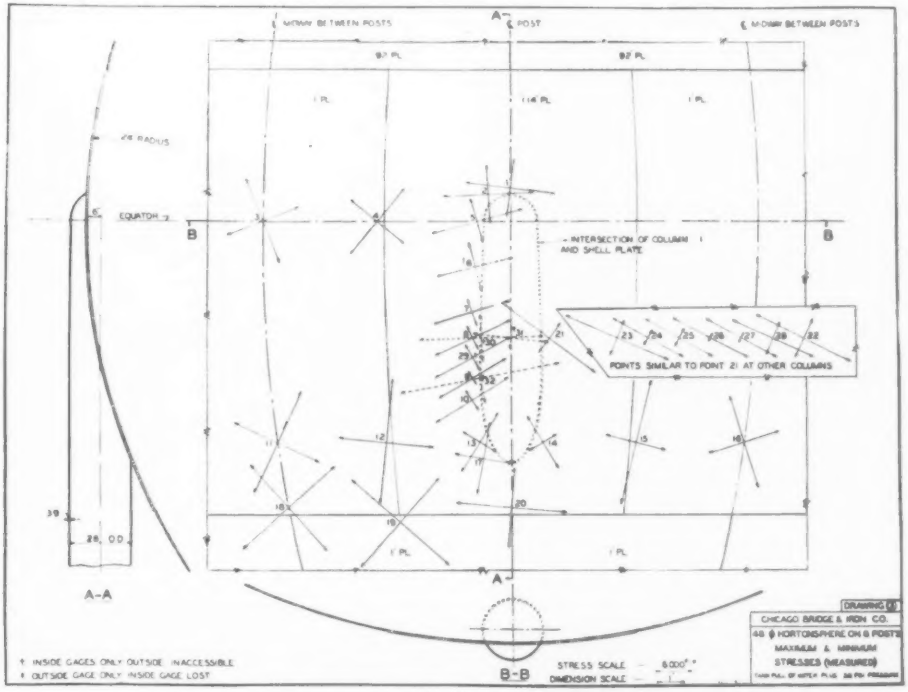
PREPARATION

Since the vessel was to be tested with water, rosette gages placed on the inside surface of the shell had to be protected against full submergence plus as much as 93 psi hydrostatic pressure. The following procedure was used and is recommended for future tests:

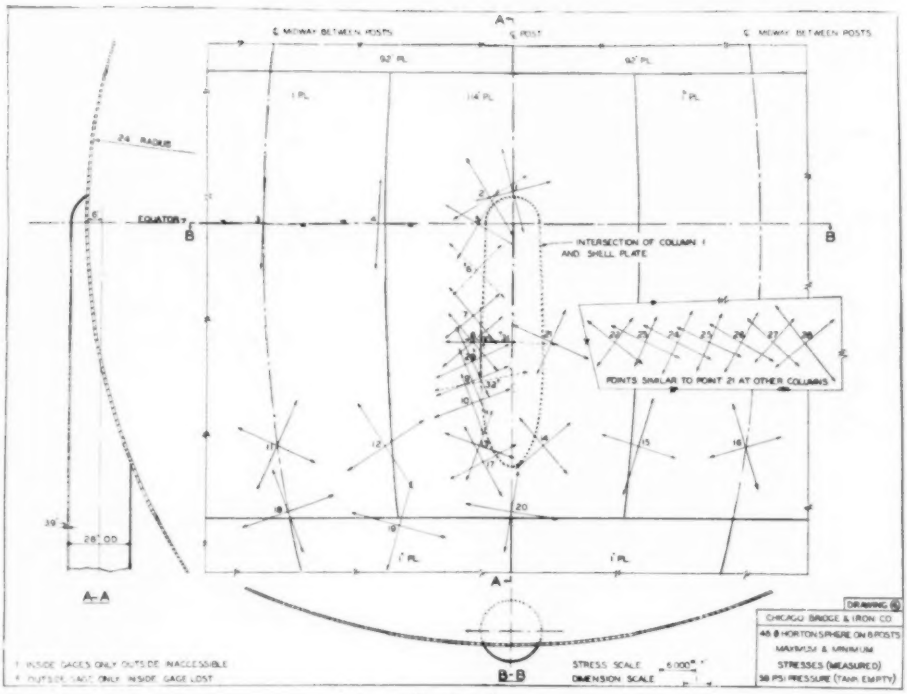
1. Preparation of Steel
   (*a*) Each point was located accurately.
   (*b*) The region around each point was ground smooth at the center and to bare metal within 14-in. diameter circles for the inside delta rosettes (8-in. diameter circles for the outside delta rosettes, and 6-in. diameter circles for single gages).
   (*c*) Vertical and horizontal scratch lines were drawn to orient the gages. The bases of the delta rosettes were placed horizontally. (The single gages were placed vertically on the columns.)
2. Preparation of Wire Leads
   (*a*) Cable-holding devices were tack welded to the



Drawing 2



Drawing 3



Drawing 4

shell about 7-in. above and to one side of each point.

(*b*) Four conductor jacketed cables were marked and strung from each rosette through a stuffing tube to the control switches. During this test it was found that the cable should be such that no change in sensitivity or readings occurs when the air surrounding the jacket is replaced by water. (See explanation under "Waterproofing Results.")

(*c*) At one end the four conductors were soldered to three gage leads and one common lead (as shown in Fig. 3). At the other end the four conductors were soldered to forked lugs which in turn were connected to the binding posts of the control equipment (shown in Fig. 7).

(*d*) The cable jackets were made watertight inside the tank. At the gage end (shown in Figs. 3 and 5) the jacket was wrapped tightly with wire and the cable was attached so that the jacket extended about 3 in. into the compound B. The stuffing tube consisted of a straight pipe 15 in. long with a bolted flange on one end and a pipe cap with a hole

Fig. 3 Close-up of rosette gage after wiring

Fig. 4 Outside gages around top of column completely waterproofed

in it just large enough to pass the cables at the other end. With the cables in place, the 15-in. pipe was heated and filled with compound B.

3. Installation of Gages
   (*a*) The surface was cleaned with acetone and the area to be covered by the gage was outlined with strips of masking tape.
   (*b*) The gages were cemented to the shell in accordance with the manufacturers' recommendations. Since the cement is not waterproof, it was applied only to the region inside the tape.
   (*c*) The gages were allowed to air dry overnight or for at least six hours.
   (*d*) The region around each gage was heated with an infrared lamp at least 1 hr, or until the resistance between the gage and the shell was over 200 megohms. The gages that could not meet this requirement were replaced.

Fig. 5 Inside gages completely waterproofed

4. Waterproofing of Gages
   (*a*) The masking tape was removed and petrosene. A wax was painted over the gage and about 1 in. beyond the edge of the cement while the plate was still warm. The gages were wired at this time.
   (*b*) As shown in Fig. 5, a paper pocket was formed over each inside gage so that there was at least 1 in. of continuous clean metal around the edge of the petrosene. An adhesive cement was applied to three edges of the paper and to the corresponding area on the shell. The pocket was pressed into place, leaving the top edge open.

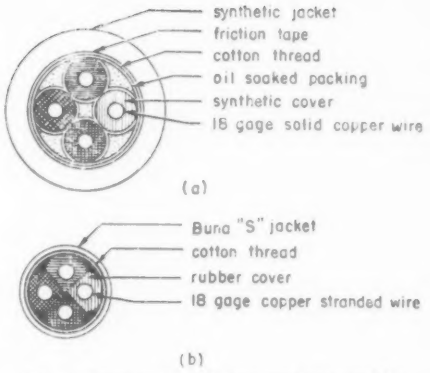


Fig. 6 Cross sections of four conductor cables

   (*c*) While the plate was kept warm, Novoid insulating compound B was poured into the pocket or directly over the gage if horizontal. This was usually done while heating the outside gage on the opposite side of the shell.
   (*d*) As shown in Figs. 3 and 4, a mound of vaseline was formed over the outside gages to provide additional protection from the elements for the gages and the leads.

5. Circuit Tests
   (*a*) The gage resistance (120 ohms) was checked to insure a continuous circuit.
   (*b*) The paper pocket and the surrounding region were saturated with water and the resistance between the gage and the shell was checked. Sometimes a wire lead penetrates the waterproof covering; if so, the paper may be removed and melted compound B may be added over this point.
   (*c*) The gages were checked with dummy gages to be sure their range was within the limits of the indicator.

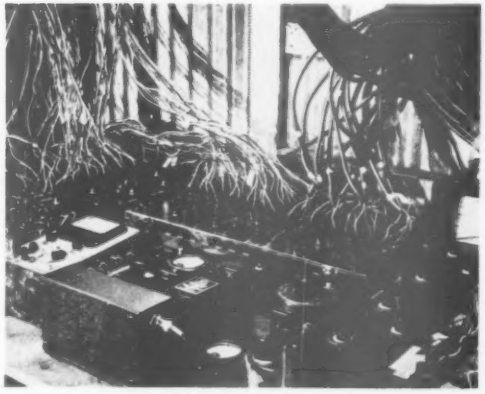


Fig. 7 The control board showing three switching boxes around; megohmmeter, Baldwin strain indicator, voltmeter and voltage regulator

TEST PROCEDURE

Since the vessel was a new commercial installation, the regular series of tests were made first. Readings were taken during these tests at convenient times, without regard to time of day or length of time between readings. These readings, except those taken close together on the same day, were erratic and were used only as a check on the other readings.

Upon completion of these tests the tank was filled one day and emptied the next. Readings (empty, full and empty) were taken on three consecutive nights after the entire tank had reached a temperature of about 50° F. These readings were very consistent and the final readings were very close to the initial readings.

A complete log of the loading sequence and the readings taken follows:

Reading No.	*Date*	*Time*	*Loadings*
1	10-22-47	7:00 A.M.	Initial—tank empty
2	10-23-47	9:00 A.M.	Tank full of water
Not taken	10-23-47	...	Tank full of water + 93 psi.
3	10-23-47	2:30 P.M.	Tank full of water + 58 psi.
4	10-24-47	8:30 A.M.	Tank full of water
5	10-28-47	8:30 A.M.	Tank empty
6	10-28-47	4:30 P.M.	58 psi. air (tank empty)
7	10-29-47	7:30 P.M.	Initial—tank empty
8	10-30-47	4:30 P.M.	Tank full of water + 29 psi.
9	10-30-47	6:00 P.M.	Tank full of water
10	10-31-47	6:30 P.M.	Tank empty

Strains were desired for three load increments—full water load, 58 psi. pressure (tank full), 58 psi. air pressure (tank empty) and a combination of the first two which approximates the maximum working conditions. For the full water load the average of reading No. 9 minus 7 and 9 minus 10 was used. For the 58 psi. pressure (tank full) the average of reading No. 3 minus 2 and 3 minus 4 was used for the outside gages and 3 minus 2 was used for the inside gages. For 58 psi. air pressure (tank empty) reading No. 6 minus 7 was used.

Two complete sets of readings were taken and averaged for each loading listed above except readings No. 6 and 8, where only one set was taken because of the time element. The column gages were not read under pressure loads since we were interested only in their total load.

COMPUTATIONS

The modulus of elasticity divided by 1,000,000, E, was taken as 29, and Poisson's Ratio, u, was taken as 0.28 for all calculations.

Since the stresses in the columns were uniaxial, the measured strain in microinches was multiplied directly by 29 to obtain the stress.

However, shell stresses were biaxial and, since the gages have width, a transverse correction must be applied to the apparent strains to obtain the true strains. Let R_1, R_2 and R_3 be the apparent strains in microinches, and e_1, e_2 and e_3 be the true strains in microinches. Then:

$$e_1 = R_1 - 1/b\,(R_2 + R_3)^*$$
$$e_2 = R_2 - 1/b\,(R_1 + R_3)^*$$
$$e_3 = R_3 - 1/b\,(R_1 + R_2)^*$$

where $1/b$ is the auxiliary factor of the gage. This factor was taken as 1/65 for all calculations.

Substituting the above equations into expressions for the principal stresses from a 60° or equiangular (delta) rosette gives

$$T_{max.} = \frac{E}{1-u^2}\Big[1/3\,(1 - 2/b)\,(1 + u)\,(R_1 + R_2 + R_3) + \sqrt{2/3}\,(1 + 1/b) \times (1 - u)\sqrt{(R_1 - R_2)^2 + (R_1 - R_3)^2 + (R_2 - R_3)^2}\Big]$$

$T_{min.}$ = The same equation as for $T_{max.}$ except a minus sign between the two terms in the brackets.

$$\tan 2\phi = \frac{\sqrt{3}\,(R_3 - R_2)}{2R_1 - R_2 - R_3}$$

where $T_{max.}$ and $T_{min.}$ are the principal stresses and ϕ is the angle from R_1 to $T_{max.}$ A positive ϕ is measured counterclockwise and a negative ϕ is measured clockwise from R_1 to $T_{max.}$. A chart was prepared to give the principal stresses by plotting the radical against the sum $(R_1 + R_2 + R_3)$.

The maximum shear stress is given by

$$S_{max.} = 1/2\,(T_{max.} - T_{min.})$$

The ring stress, T_1, the meridian stress, T_2, and the tangential shear stresses on horizontal and vertical sections, S_v, are given by the following equations:

$$T_1 = T_{min.} + S_{max.}\,(1 + \cos 2\theta),$$
$$T_2 = T_{min.} + S_{max.}\,(1 - \cos 2\theta),$$
$$S_v = S_{max.}\,(\sin 2\theta),$$

where θ is the angle ϕ corrected so that it is measured from the horizontal rather than from the direction of R_1.

WATERPROOFING RESULTS

The waterproofing of the inside gages was very successful, since only one inside gage was lost during the investigation, and this was lost just after it had been waterproofed. If time had permitted, it would have been replaced before the test.

The jacketed cables caused the only trouble encountered. As was found before when using long single leads, if not properly protected, a drop in the readings will be experienced when water replaces air as the medium surrounding the leads. This was formerly overcome by using the cable shown in Fig. 6 (*a*); however, difficulty was encountered in sealing the ends of this cable. On this test the cable shown in Fig. 6 (*b*) was used and the same trouble as was encountered with

* See "Practical Reduction Formulas for Use on Bonded Wire Strain Gages in Two-Dimensional Stress Fields," by R. Baumberger and F. Hines, Vol. II, No. 1, Experimental Stress Analysis.

TABLE I — MAXIMUM AND MINIMUM STRESSES IN SHELL PLATES

Point		Tank Full of Water			Tank Full of Water Plus 58 psi Pressure		
		T. Max.	T. Min.	θ	T. Max.	T. Min.	θ
The following gages outline as closely as possible the intersection of the column with the 1.14" shell plate.							
	Outside	2,325 psi	— 475 psi	— 1°	10,550 psi	7,850 psi	— 3°
1	Inside	1,050	— 2,000	— 8	4,800	2,200	— 12
	Average[a]	1,650	— 1,250	— 4.5	7,650	5,000	7
	Outside	2,675	— 275	3.5	10,050	7,500	0
2	Inside	500	— 2,600	1.5	5,350	2,300	3.5
	Average	1,600	— 1,450	2.5	7,700	4,900	2
	Outside	2,150	— 850	16	9,000	6,100	8
5	Inside	1,700	— 2,850	16	6,900	1,700	20.5
	Average	1,900	— 1,850	16	7,950	3,950	16
	Outside	800	— 1,950	20	6,700	4,100	14
6	Inside	Gage lost					
	Outside	550	— 2,600	30	7,950	4,650	19
7	Inside	2,500	— 3,600	17.5	5,550	150	17
	Average	1,500	— 3,050	21.5	6,800	2,400	17.5
	Outside	225	— 3,150	34.5	7,650	3,350	26
8	Inside	2,800	— 3,500	22	6,200	1,000	24.5
	Average	1,500	— 3,300	26.5	7,000	2,200	25
	Outside	— 275	— 3,800	37.5	6,950	2,900	29
29	Inside	3,650	— 1,650	23	7,400	2,250	27.5
	Average	1,600	— 2,600	29	7,200	2,550	28.5
	Outside	— 700	— 3,525	44.5	6,000	2,600	33
9	Inside	3,300	— 3,200	27.5	7,200	0	29
	Average	1,100	— 3,400	33	6,600	1,350	30
	Outside	— 1,100	— 3,950	43.5	5,500	2,700	34
10	Inside	2,700	— 2,600	34.5	8,800	1,200	31
	Average	800	— 3,250	37.5	7,200	2,000	32
	Outside	— 800	— 3,400	57.5	5,700	3,000	51
13	Inside	1,100	— 1,300	64	6,250	3,500	65.5
	Average	100	— 2,300	62.5	5,950	3,300	58
	Outside	— 475	— 2,800	48	6,000	3,100	39.5
17	Inside	1,200	— 2,000	— 69.5	7,900	2,900	— 82
	Average	— 400	— 1,700	88	6,100	3,900	80.5
	Outside	— 400	— 2,650	— 54.5	5,500	3,150	— 47
14	Inside	100	— 2,400	— 63	4,800	1,950	— 67
	Average	— 150	— 2,550	— 59	5,100	2,650	— 58
	Outside	0	— 3,200	— 34	7,800	3,400	— 27.5
21	Inside	7,100	— 1,350	— 40	11,900	2,800	— 42
	Average	3,550	— 2,250	— 38.5	9,750	3,150	— 37

[a] The average stresses were obtained by averaging the outside and inside strains of opposite gages and computing as a single rosette.

TABLE I—continued

Point		Tank Full of Water			Tank Full of Water Plus 58 psi Pressure		
		T. Max.	T. Min.	θ	T. Max.	T. Min.	θ
The following gages were placed on the inside surface only opposite the edge of the column.							
30	Inside	6,050 psi	— 1,000 psi	4°	10,400 psi	3,950 psi	1.5°
32	Inside	7,450	— 50	11	13,500	4,350	10.5
The following gage was placed on the inside surface only and on the center line of the column.							
31	Inside	350	— 2,250	— 5	6,400	1,950	— 5.5
The following gages were located at various regions within 3½" of weld seams.							
	Outside	2,950	900	27	14,100	9,700	13.5
4	Inside	— 100	— 2,000	27	3,500	— 1,050	85.5
	Average	1,450	— 550	27	7,250	5,900	51
	Outside	3,975	2,075	89.5	14,900	13,750	— 31
12	Inside	2,200	100	80.5	7,150	1,200	80
	Average	3,100	1,100	85	10,600	7,950	84.5
	Outside	3,500	1,375	— 85	13,650	13,000	— 47
15	Inside	900	— 1,350	88	7,900	— 2,900	75
	Average	2,200	0	— 88	10,700	5,250	76
	Outside	3,550	2,250	88	13,150	11,850	— 87.5
18	Inside	2,000	1,550	65	8,650	6,600	20
	Average	2,800	1,950	82.5	10,350	9,700	41.5
	Outside	3,950	2,350	— 85	14,200	11,300	87
19	Inside	1,950	800	— 69	9,700	5,850	— 17
	Average	2,900	1,600	— 78	10,700	9,800	— 41
	Outside	3,300	2,075	— 89	11,900	11,400	— 74
20	Inside	1,450	— 1,100	— 3	7,100	1,600	— 2
	Average	1,750	1,100	— 7	9,300	6,700	— 4
The following gages were located midway between columns on the 1" shell plates.							
	Outside	1,850	1,850	0	10,850	9,600	— 87
3	Inside	— 500	— 1,350	— 47	4,600	3,200	— 50.5
	Average	650	250	— 47.5	7,600	6,500	— 67.5
	Outside	2,800	1,500	84	10,050	8,700	70
11	Inside	2,400	1,500	78	8,950	6,850	62
	Average	2,550	1,500	81.5	9,500	7,800	65.5
	Outside	2,400	925	— 87	8,900	6,900	— 73.5
16	Inside	450	— 300	87	7,300	5,350	— 70
	Average	1,450	300	— 89	8,100	6,150	— 72.5

the single leads returned; however, the end sealing problem was solved.

Because of this drop in readings, strains due to full water load determined from inside gage readings had to be corrected. Using the leads that were used for the test, readings were taken in the laboratory for a series of load increments with the leads remaining in air. Then, after an initial reading in air, the leads were submerged in water and readings were taken for the same series of load increments. Plotting the strain obtained when the leads remained in air against the corresponding strain obtained when the leads were in air for the initial reading and in water for the loaded reading gave a straight line expressed by the formula:

$$\text{Corrected strain} = 0.9\,(\text{indicated strain}) + 150$$

This formula was used to correct the inside surface strains due to full water load only. The medium surrounding the leads remained the same for both readings used to determine the pressure strains and the outside surface strains, so no correction was required.

STRESSES—MEASURED

The maximum and minimum stresses as computed from the measured strains are plotted on drawings 2, 3 and 4 for full water load, full water load plus 58 psi. pressure and for 58 psi. air pressure with the tank empty, respectively. The stresses for the first two load conditions are listed in Table I.

Drawing 5 plots the tangential shear stresses and the T_1 stresses on the edge cut by a vertical plane A which forms a 3°-30 ft. angle at the center of the sphere with plane B, plane B being a vertical plane through the axis of the column and the center of the sphere. A cut section was formed by plane A and horizontal planes passed through points 2 and 17 at the top and bottom of the intersection. The section was assumed to be symmetrical about plane B. The summation of the force components in both the vertical and horizontal directions are also shown on this drawing, and they show a reasonable balance.

The plot of the shear stresses indicates that they are nearly uniform along the vertical portion of the intersection, which agrees with the assumption made in design. The plots for full water load and for the combined loads are quite similar, as would be expected.

The plot of the T_1 stresses for full water load, however, indicates that a band of the shell acts as a beam to transfer the load to the column. The T_2 stresses for the full water load indicate that compression exists in the vertical direction over the entire length of the intersection.

In Table I the points near welds show higher stresses for the outside surface than for the inside surface, indicating some inward peaking of the seams. The measured strains indicated that this caused yielding at point 18 during the overload test. However, after the overload test had stress relieved this region, the measured stresses were below the allowable. A graphical explanation of this is given in Drawing 6.

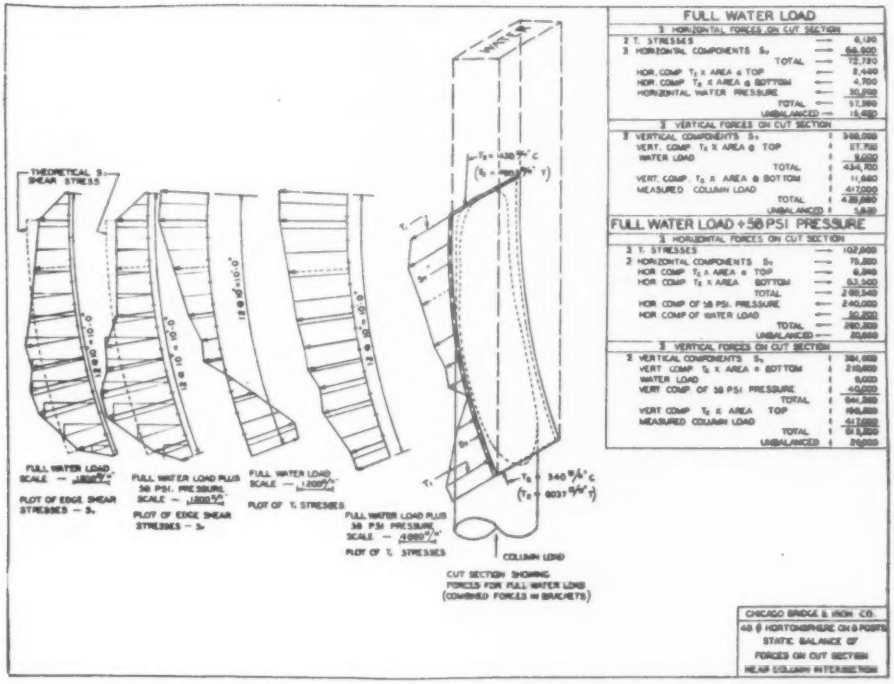
The water load test indicated the same bending previously found at the edge of the column in the 51-ft. diameter sphere. The column tends to move in at the top under water load. When the pressure is added to the water load, the column moves back out thereby somewhat relieving the bending stress. That is, these stresses are not additive.

The extreme fiber stress due to this bending at the intersection would undoubtedly increase for the same sphere designed for a lower working pressure. An idea of the magnitude of this fiber stress may be obtained by assuming that the same bending moment would exist in the thinner shell. This bending moment on a

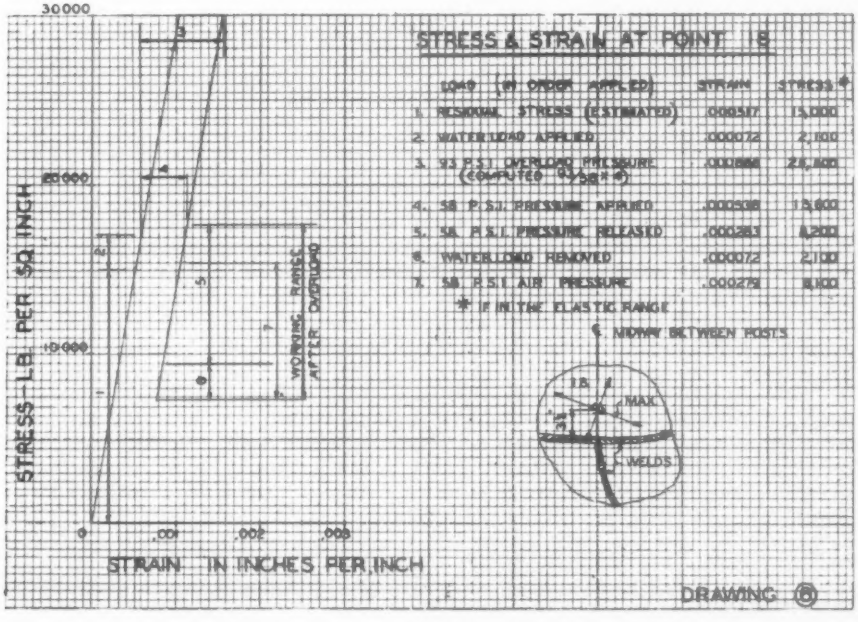
TABLE II—Comparison of Measured and Theoretical T_1 and T_2 Stresses

Point		Full Water Load			58 psi Pressure		Full Water Load + 58 psi Pressure		
		T_1	T_2	S_s	T_1	T_2	T_1	T_2	S_s
Points on or near the equator.									
2	Measured	1,580	− 1,430	130	7,380*	7,517*			
					6,072**	6,352**	7,695	4,905	93
	Theoretical	2,080	435	—	7,300	7,300	9,380	7,735	—
3	Measured	447	478	− 212	6,947	7,777			
					6,245	6,982	6,685	7,435	− 375
	Theoretical	2,500	500	0	8,300	8,300	10,800	8,800	0
4	Measured	1,020	− 145	800	6,170	7,532			
					5,302	6,842	6,420	6,705	677
	Theoretical	2,500	500	715	8,300	8,300	10,800	8,800	715
5	Measured	1,640	− 1,562	1,000	6,595	6,742			
					5,985	5,817	7,600	4,250	1,053
	Theoretical	2,190	438	1,430	7,300	7,300	9,490	7,738	1,430
Points near plane through bottom of column intersection.									
11	Measured	1,527	2,577	159	7,252	7,997			
					6,507	6,092	8,087	9,190	652
16	Measured	315	1,425	− 19	6,320	7,280			
					5,982	6,495	6,320	7,905	− 585
	Theoretical	1,437	2,590	0	8,300	8,300	9,737	10,890	0
12	Measured	1,117	3,057	179	7,847	8,152			
					6,860	7,515	7,962	10,543	242
15	Measured	22	2,192	− 52	6,675	8,325			
					5,545	8,060	5,575	10,250	1,189
	Theoretical	1,437	2,590	+715	8,300	8,300	9,737	10,890	± 715
13	Measured	− 1,745	− 455	1,062	6,162	6,240			
					5,810	5,640	4,023	5,202	1,179
14	Measured	− 1,887	− 790	− 1,037	6,032	6,017			
					5,220	5,205	3,315	4,390	− 1,098
	Theoretical	1,260	2,270	+ 1,430	7,300	7,300	8,560	9,570	± 1,430
17	Measured	− 1,695	− 340	50	6,322	6,575			
					5,610	6,437	3,913	6,037	387
	Theoretical	1,320	2,280	—	7,300	7,300	8,620	9,580	—
Points near the bottom girth seam of equator plates.									
18	Measured	1,940	2,730	109	8,015	7,520			
					8,197	7,202	10,132	9,993	302
	Theoretical	1,695	2,640	0	8,300	8,300	9,995	10,940	0
19	Measured	1,655	2,870	− 263	8,147	7,777			
					8,080	7,320	10,335	10,190	− 450
	Theoretical	1,750	2,650	0	8,300	8,300	10,050	10,950	0
20	Measured	1,757	1,055	− 75	7,687	6,937			
					7,542	5,677	9,265	6,735	− 162
	Theoretical	1,490	2,320	0	7,300	7,300	8,790	9,620	0

* Tank empty. ** Tank full. Note: Values given are in psi.


FULL WATER LOAD
3 HORIZONTAL FORCES ON CUT SECTION
2 T. STRESSES
3 HORIZONTAL COMPONENTS S_H
TOTAL
HOR. COMP T_2 x AREA @ TOP
HOR. COMP T_2 x AREA @ BOTTOM
HORIZONTAL WATER PRESSURE
TOTAL
UNBALANCED
3 VERTICAL FORCES ON CUT SECTION
3 VERTICAL COMPONENTS S_V
VERT. COMP T_2 X AREA @ TOP
WATER LOAD
TOTAL
VERT. COMP. T_2 X AREA @ BOTTOM
MEASURED COLUMN LOAD
TOTAL
UNBALANCED
FULL WATER LOAD + 58 PSI PRESSURE
3 HORIZONTAL FORCES ON CUT SECTION
2 T. STRESSES
2 HORIZONTAL COMPONENTS S_H
HOR. COMP T_2 x AREA @ TOP
HOR. COMP T_2 x AREA @ BOTTOM
TOTAL
HOR. COMP OF 58 PSI PRESSURE
HOR. COMP OF WATER LOAD
TOTAL
UNBALANCED
3 VERTICAL FORCES ON CUT SECTION
2 VERTICAL COMPONENTS S_V
VERT. COMP T_2 x AREA @ BOTTOM
WATER LOAD
VERT. COMP. OF 58 PSI PRESSURE
TOTAL
VERT. COMP T_2 x AREA @ TOP
MEASURED COLUMN LOAD
TOTAL
UNBALANCED
THEORETICAL S SHEAR STRESS
FULL WATER LOAD SCALE — 1000 P.S.I.
PLOT OF EDGE SHEAR STRESSES — S_V
FULL WATER LOAD PLUS 58 P.S.I. PRESSURE SCALE — 1000 P.S.I.
PLOT OF EDGE SHEAR STRESSES — S_V
FULL WATER LOAD SCALE — 1000 P.S.I.
PLOT OF T_1 STRESSES
FULL WATER LOAD PLUS 58 P.S.I. PRESSURE SCALE — 1000 P.S.I.
PLOT OF T_1 STRESSES
COLUMN LOAD
CUT SECTION SHOWING FORCES FOR FULL WATER LOAD (COMBINED FORCES IN BRACKETS)
CHICAGO BRIDGE & IRON CO.
48 ϕ HORTONSPHERE ON 8 POSTS
STATIC BALANCE OF FORCES ON CUT SECTION
HEAD COLUMN INTERSECTION

Drawing 5


30000
STRESS - LB. PER SQ. INCH
STRAIN IN INCHES PER INCH
.001
.002
.003
WORKING RANGE AFTER OVERLOAD
STRESS & STRAIN AT POINT B
LOAD (IN ORDER APPLIED)
STRAIN
STRESS *
1. RESIDUAL STRESS (ESTIMATED) .000537 15,000
2. WATER LOAD APPLIED .000072 2,100
3. 93 P.S.I. OVERLOAD PRESSURE (COMPUTED @ 58 P.S.I.) .000888 26,400
4. 58 P.S.I. PRESSURE APPLIED .000508 15,600
5. 58 P.S.I. PRESSURE RELEASED .000283 8,200
6. WATER LOAD REMOVED .000072 2,100
7. 58 P.S.I. AIR PRESSURE .000279 8,100
* IF IN THE ELASTIC RANGE
B MIDWAY BETWEEN POSTS
MAX.
WELDS
DRAWING B

Drawing 6

1-in. strip at point 32 was found to be $M = S_M t^2/6 = (7150)\ (1.14)^2/6 = 1548$ in.-lb., where S_M = the measured fiber stress due to bending. If the same sphere were designed for a 30 psi. working pressure, the required thickness of the shell plate, t, at the post would be 0.73 in. Then the maximum fiber stress for the thinner sphere for the same bending moment, M, would be $S = 6M/t^2 = (6)\ (1548)/(0.73)^2 = 17{,}420$ psi. under test or $S = 17{,}420\ (48/62.4) = 13{,}400$ psi. under working conditions.

Table II compares the measured and theoretical ring stresses, T_1, and the meridian stresses, T_2. The points in planes through the top and bottom of the intersection are not in very close agreement. However, in the region away from the intersection there is close agreement.

The column loads and stresses are given on Drawing 1. These loads varied from 380 kips on column 5 to 450 kips on column 6. Column 1, which was investigated thoroughly, carried 417 kips or 2% more than the average 409 kips. The single points on the shell near each of the columns indicated a somewhat similar distribution of load.

CONCLUSIONS

The tubular column support conveniently picks up the load from the shell by nearly equal shear stresses acting along the vertical portion of the intersection.

The top of the column moves in under full water load and induces bending in the shell at the edge of the intersection. However, these stresses are not directly additive to the pressure stresses. The pressure load rounds up the shell and moves the top of the column back out.

For the sphere tested, the entire shell in the region of the column was compressed in the vertical direction under water load. This involves a reversal of stress under pressure; however, when the magnitudes of the maximum average tension and the maximum average compression were added, the result was below the allowable.

The thickness of the shell plate at the column appears to be somewhat conservative; however, because of the many factors involved, it is recommended that the present practice of increasing the thickness of this plate be continued.

The maximum average stress in the lower edge of the equator plates between the post plates is very near the allowable and therefore justifies using the same thickness for these plates as is used for the bottom plates.

The method of waterproofing was very satisfactory; however, the four conductor cables should be improved.

Comparison of Notch Tests and Brittleness Criteria

Discussion by Wendell P. Roop

In this discussion the term "thickness" will refer to the dimension of a plate determined by the separation of the rolls, and width will be measured in the direction of width in the plate, regardless of its relative magnitude in the test specimen.

A basic difference occurs between the types of specimen studied with respect to direction of advance of the fracture. In the Kahn and State College tests the crack moves forward in width and thus encounters conditions in the metal which do not vary at different stages of the advance. In the Lehigh test the crack advances in thickness. In making the notch one of the all-important skin surfaces is removed; the energy needed to start fracture is expended on metal lying at the depth of the notch from the rolled surface. The energy needed to propagate the crack is affected by the changing nature of the metal at varying distances from the rolled surfaces. The skin on the surface opposite the notch makes no contribution to the final result.

The idea of a transition function which drops off from the ductile level in two steps as temperature is reduced has interesting implications. The authors identify these two steps with transitions controlled (1) by the machined notch and (2) by the "sharp crack formed by shear fracture." The lower step (T_N) occurs when the criterion refers to deformations at the beginning of fracture, and the upper step (T_B) to conditions during or at the end of fracture. Among the diagrams figured, Types *B* and *C* (as in Fig. 4) which include both steps seem not to occur under a single criterion; Fig. 7 (*D*) may present a rather vague exception on this point. But the fact that a distinction exists between a criterion based on starting fracture and one based on propagating fracture is surely sound, and is confirmed by these tests.

The transition temperature based on the start of fracture is reported in these tests to fall consistently lower, by a large differential, than that based on what happens at later stages. From this we might infer that to start a fracture in the brittle mode calls for a lower temperature than that needed to convert a fracture to the brittle mode after it has started in the ductile mode.

Such an inference, however, seems at variance with the effect of cutting the original notch diagonally, as reported by Thomas and Windenburg in the *Welding Research Supplement* for April 1948. The diagonal cut favors ductility and depresses the transition by an amount like the difference between T_N and T_B. A fracture begun in the ductile mode would thus seem to need a substantial reduction of temperature to persuade

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The paper by Osborn, Southbrook, Stout and Johnston was published in the *Welding Research Supplement*, January 1949, p. 24-s.

it to turn brittle, as compared with the temperature at which the fracture might be brittle from the start.

There seems to be general agreement that even at low temperatures "a small zone immediately below the notch continues to fail in a ductile manner." This same fact has also been described by saying that flow always precedes even a brittle fracture. Brittleness therefore must assert itself somehow in the presence of a natural crack which is higher in acuity than any machined notch. The mechanism by which the machined notch affects ductility is thus more intricate than has usually been supposed. Any data which shed light on this matter would be most welcome, and if the authors by further study of their detailed data could clarify their interpretation in this respect an important contribution to knowledge would be made.

As a significant fact it is noted that the Kahn test discriminates between two acuities, both high, only in the energy needed to start fracture in the ductile mode. Beyond a certain threshold value the acuity does not affect energy needed to propagate fracture nor the transition found by this criterion. In $^3/_4$-in. plate a jeweler's saw cut and a No. 47 drill give the same result and for convenience the drilled hole is preferred.

As a final comment it is noted that the transition by appearance of fracture as reported in the tabular data for all three types of specimen is higher in $1^1/_4$ in. than in $^5/_8$ in. thickness by 63±20°. But the methods used afford no clue as to whether this is a geometrical or a metallurgical effect.

Authors' Reply

The authors appreciate the discussion submitted by Professor Roop.

The difference existing between the modes of fracture advance for the Lehigh notch-bend test and for the tear and Schnadt-type tests is quite validly pointed out by Professor Roop. Unfortunately, no evidence has ever been published that tests in which fracture proceeds along the plate width are more significant in evaluating service performance than are tests producing fractures through the thickness. Service failures usually involve propagation of the crack along the plate width (or length), but initiation of the failure may well take place through the thickness.

The data of Thomas and Windenberg in the April 1948, *Welding Research Supplement* illustrate nicely the separation of transition temperatures as measured by ductility (T_N) and those as measured by fracture appearance (T_B). In a paper resulting from a separate project Stout and McGeady (June 1948, *Welding Research Supplement*) also showed that notch acuity affected ductility transition temperature much more than fracture transition. As the notch attains high acuity, the two transition temperatures tend to approach one another.

It is true that Type *C* curve (Fig. 4) does not appear in Figs. 5, 6 or 7, but examples of this type did occur in curves obtained for some tests on A-70 steel in $^5/_8$-in. plate thickness. Figure 7 (*D*) is an excellent example of Type *B* in Fig. 4.

In the present tests, essentially two measures of the behavior of the steel in the presence of a notch have been considered. First, the amount of plastic flow experienced by the steel before any extensive cracking occurs has been measured by lateral contraction at the notch root. Second, the manner in which the crack propagates through the test section has been observed, and classified as shear or cleavage fracture in percentage terms. The first measurement is highly dependent on the machined notch geometry. The second is relatively independent of the original notch. Kahn and Klier, *et al.*, used measurements of the second type only.

Since all specimens tested were machined to $^5/_8$ in. thickness, the tests made on plates of different rolled thicknesses were of constant geometry. The higher fracture transition temperatures exhibited by the $1^1/_4$-in. plates over the $^5/_8$-in. plates are very likely due to metallurgical effects. Tests made on specimens normalized in specimen size have indicated that most of the difference between $^5/_8$- and $1^1/_4$-in. rolled plates is wiped out by the normalizing treatment.

The authors are indebted to Professor Roop for his interesting remarks on this perplexing subject.

Correction

In the paper "Corrosion Resistance of Powder-Cut Stainless Steels" by L. E. Stark and C. R. Bishop, published in the March 1949 *Supplement* an error occurs in the order of photographs in Fig. 13, page 109-s. Photographs of specimens No. 1M and 1H are reversed. The photograph of the specimen identified as 1M is in reality specimen No. 1H and the photograph of the specimen identified as 1H is specimen No. 1M. The photographs and text intend to show that the heat effect from welding a machine-beveled edge is comparable to that from welding a powder-cut edge and that heat treatment after welding eliminates the heat-affected zone.

Effect of "Quench Time" on Weld Metal

Results of various postwelding quench times on the ductility of all-weld-metal tensile coupons prepared with Type E6011 electrodes are presented, including the effect of a critical quantity of hydrogen

by Jay Bland

Abstract

Results of various postwelding quench times on the ductility of all-weld-metal tensile coupons prepared with Type E6011 electrodes are presented. An attempt is made to explain the presence of fissures causing the low ductilities found for specimens quenched within 1 to 3 min. after welding. Some experimental evidence for considering a critical quantity of retained dissolved hydrogen as the responsible agent for fissure formation is presented. Additional considerations of the phenomenon are offered.

INTRODUCTION

THE extraordinary advances in welding and welded fabrication, brought about by the necessities of the recent war, required practical applications of welding materials and procedures ahead of their specification development, and certainly far ahead of the basic knowledge of the phenomena of the welding process.

In the latter part of 1945, the Navy Department revised the requirements for medium steel electrodes and issued an interim specification[1] for them. Early in 1946 a program for the requalification of electrodes under this specification was authorized to be conducted at the Material Laboratory, New York Naval Shipyard.

The revised specification requires that in the fabrication of groove welds for all-weld-metal tensile coupons, the assembly "shall be heated in boiling water for five minutes prior to welding. Within ONE minute after the completion of each LAYER, including the last layer, the assembly shall be immersed in boiling water." This procedure was adopted in place of the 10-min. delay period previously specified in order to speed up the production of the groove weld assemblies, and to prevent manipulation of test results.

When evaluations of Type E6011 electrodes were undertaken in the course of the requalification program, it was observed that the ductility properties of most of the available brands were unsatisfactory, being considerably below the minimum requirement of 22% as-welded (elongation in 2-in. all-weld-metal coupon). It was suspected that the 1-min. delay between completion of welding and immersion in boiling water was too short an interval and was a contributing cause for the low ductilities observed, possibly because it did not allow the hydrogen, known to promote embrittlement of steel, to evolve from the weld metal.

An investigation was made to determine the validity of and evidence for the above concept, and to determine the effect of various delay intervals on the properties of the weld metal. This paper presents some of the work performed at the Material Laboratory, New York Naval Shipyard, in connection with this investigation.

A search through available literature on the subject indicated that most of the previous investigations of welds exhibiting low ductility properties were concerned with the causes and means of correction of the so-called "fish eyes" or flakes in the deposited weld metal, which appeared to be due to hydrogen. Herres[2] showed that the degree of hydrogen embrittlement (localized or general) of weld metal and of the heat-affected zone of the base metal is dependent upon the microstructure of the steel and the rate and temperature of straining; he suggested a precipitation reaction as the probable cause of embrittlement during straining. Lefevre[3] compared the origin and appearance of weld metal flakes with those observed in low-alloy forged steel and suggested thermal treatments for their elimination. Voldrich[4] considered the formation of underbead cracking as a hydrogen embrittlement phenomenon, and attempted to evaluate and correlate the two. Van den Blink[5] showed the influence of the water content of electrode coatings on the hydrogen content of the weld metal based on partial pressure considerations. Flanigan[6] investigated the effect of hydrogen on the ductility of arc welds in mild steel. In his attempt to study the effect of cooling rates and incidentally to measure the amount of dissolved hydrogen, he quenched weld metal samples upon completion of welding; he found very low weld metal duc-

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The opinions expressed herein are those of the author and do not necessarily represent the opinions of the Navy Department.

tility, and observed microcracks in the E6010 weld metal deposit. Flanigan thus appears to have been among the first investigators to observe and record the presence of actual fissures in the weld metal.

GENERAL CONDITIONS OF TEST

The welding procedure used for making all physical test plates reported herein, except as noted, was as required in Figs. 3 and 3 (*A*) of the interim specification.[1] The test assemblies were of medium steel $^3/_4$ x $10^1/_2$ x 12 in. with conventional flame-cut $22^1/_2°$ bevels on each plate of the test assemblies. Root openings were $^1/_2$ in. wide with $^1/_2$ in. thick backing strips. Welds were deposited using the "4-diameter split-weave" pass technique. Optimum arc currents and voltages within the manufacturer's recommended range were selected by the welder.

After the joint was tacked, the assembly was heated in boiling water for 5 min. prior to welding. At the particular quench time under investigation, the assembly was immersed in boiling water after completion of each layer, including the last layer. The assembly was removed from the boiling water within 1 min. after the increased boiling of the water had subsided, and the subsequent layer was started immediately. Quench time was measured with a stop watch in order to maintain uniformity.

After completion of welding, a strip containing the weld and approximately 1-in. base metal on each side was flame cut from the assembly and machined into two 0.505-in. diameter all-weld-metal tensile specimens in the conventional manner. In all cases the elapsed time between completion of welding and the pulling of the machined test specimens exceeded two days. The tensile specimens were pulled in a standard tensile machine with a rate of applied load of 0.05 to 0.15 in. per minute.

Throughout this investigation only $^3/_{16}$-in. diameter electrodes were used. Electrodes used were selected from pre-sample batches used in specification development, samples which had been submitted for Brand and Type Approval tests and samples of electrodes carried in stock. Selection of particular brands of electrodes was governed by their availability.

PRELIMINARY TESTS

Three brands of Type E6011 electrodes were used to prepare groove welds for tensile tests. Since the time interval between the completion of each layer and actual placing of the plate in the tank of boiling water was the important factor to be considered, the initial series of test specimens was made using the most severe quench time practicable. Quench time was kept within 20 sec., which represents the minimum time in which the plates could consistently be unclamped from the welding table and placed in the tank of boiling water. All plate assemblies at this stage were welded in one direction. (Layers were not reversed.)

Results of these preliminary tests indicated that in all but three of the tensile specimens pulled, the elongation is considerably below the 22% minimum specified. In addition, the fractures are unconventional in that they are not the usual ductile type but are brittle and woody in appearance as shown in Fig. 1. These fractures are characterized by areas of gray, silky-appearing metal surrounding clusters of jagged, irregular craters of metal with a light gray texture similar to that associated with fish eyes. The relative position of these clusters varies considerably in the fractures.

WELDING TESTS AND RESULTS

Comparison of 20-Sec. and 10-Min. Quench Time

In view of the former results it was decided to extend the tests to a larger number of brands of type E6011 electrodes and to check the physical properties of all brands using a 10-min. quench time. In addition sim-

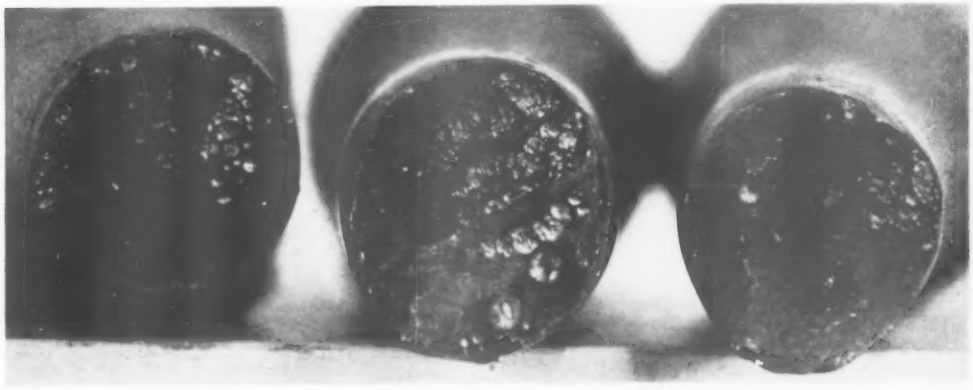
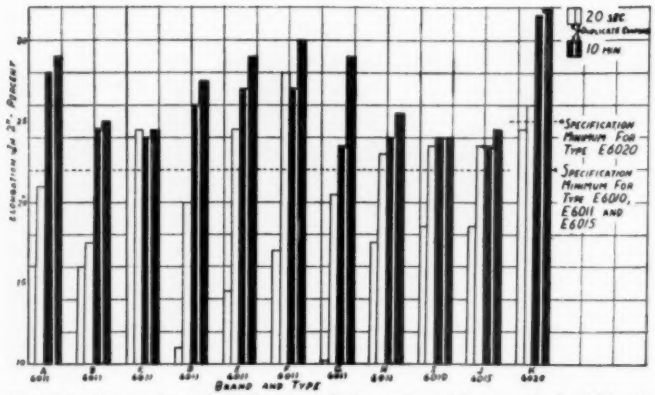


Fig. 1 Broken 0.505-in. diameter, all-weld-metal tensile specimens welded within 20 sec. quench time. Typical brittle, woody fractures



Graph 1 Comparison of medium steel electrode welds quenched within 20 sec. and in 10 min.

ilar tests were conducted with E6010, E6020, and low-hydrogen types of electrodes. Results of tests are shown in Graph 1.

At least one tensile specimen machined from each E6011 test assembly welded with a 20-sec. quench time exhibited the same woody type of fracture and low elongation noted herein; whereas the 10-min. quench time tensile specimens showed a marked improvement in elongation and type of fracture. For the latter, all values of elongation exceeded the normally expected minimum of 22%, and all fractures exhibited the gray, silky, more ductile appearance indicated in Fig. 2. These results were noted for all E6011 electrodes tested except Brand C which did not show any difference in elongation or type of fracture. In both conditions of test this electrode deposit exhibited a ductile type of fracture with acceptable elongation. At present, there is no definite explanation for this behavior. It is to be noted that Brand J, a low-hydrogen type electrode, also showed ductile fractures for both quench times. However, the physical properties were not consistently acceptable. Brand K, an E6020 type electrode welded with a 20-sec. quench time, produced one tensile specimen with a brittle, crystalline type of fracture rather than the woody type. Its elongation (24.5%) was a shade beneath 25% which is normally specified for this type, but which is usually exceeded by a considerable amount.

It may be noted that in the preparation of the above and subsequent assemblies, the direction of welding was reversed after each layer was deposited in order to maintain greater uniformity of thermal conditions.

Since the 20-sec. quench time caused such a marked decrease in elongation, a condition not usually associated with weld metal of the chemical content obtained with E6011 electrodes and since the exact cause of this reduction in elongation was not known, it was decided to extend the investigation to determine the minimum quench time at which these electrodes would exhibit ductility more in accordance with that usually expected.

Effect of Varying Quench Time from 20 Sec. to 10 Min.

In order to obtain information as to the effect of varying quench time, a series of test plates was prepared. Separate plates, using quench times ranging from 20 sec. to 10 min., were made. Brands A and B electrodes were used, primarily because of their availability and because they were typical with regard to change in elongation noted.

Graphs 2 and 3 show the data which indicate that the transition from a brittle, woody fracture for these two brands occurs somewhere between quench times

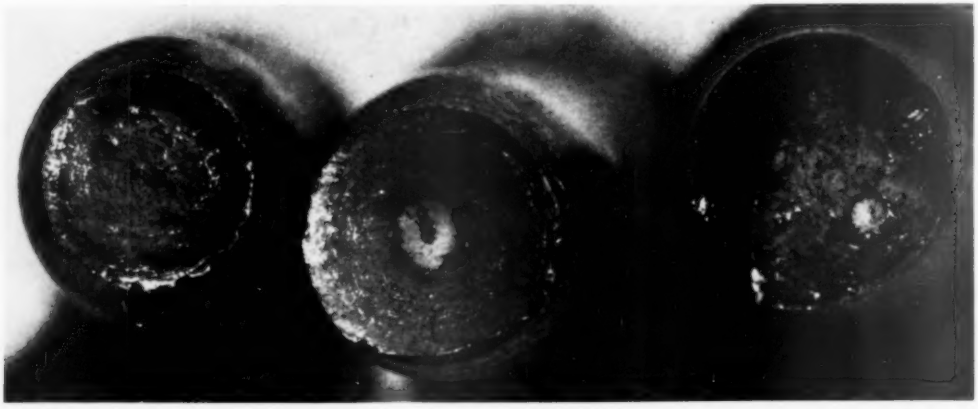
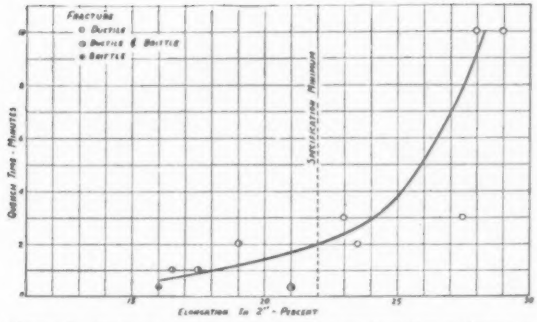
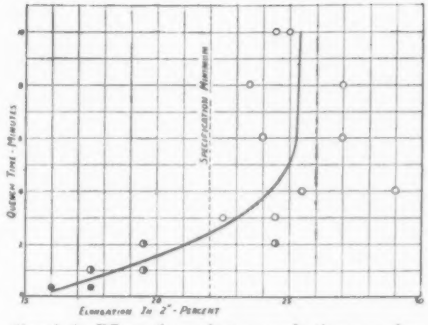


Fig. 2 Broken 0.505-in. diameter, all-weld-metal tensile specimens welded within 10 and 3 min. quench time. Typical ductile fractures



Graph 2 Effect of varying quench time on ductility of Brand A electrode weld, Type E6011, 5/32-in. diameter, d.-c. reverse polarity, duplicate coupons



Graph 3 Effect of varying quench time on ductility of Brand B electrode weld, Type E6011, 5/32-in. diameter, d.-c. reverse polarity, duplicate coupons

of 2 and 3 min. Typical fracture appearances are shown in Figs. 3 and 4. It is observed that the ductility increased with increase in quench time.

Similar tests of additional brands of E6011 electrodes indicated that three of the available brands were capable of producing tensile specimens with elongation above 22% when a quench time of at least 3 min. was used, and that only two brands could do so at shorter quench times.

It is apparent from the results obtained that a 1-min. rapid quench will cause most E6011 electrodes to exhibit surprisingly low ductility.

In order to obtain some information as to the nature of the marked reduction in the elongation of tensile specimens prepared with relatively rapid quenching conditions, the following associated tests were conducted concurrently with the above tests.

Effect of Full Weave. Two test plates were prepared using two brands of electrodes, A and B, with 1-min. and 20-sec. quench times, respectively. Both plates were welded with a full weave pass technique rather than the "4-diameter split-weave" pass technique. In the two tests conducted there was no appreciable improvement in appearance of fracture or physical properties as a result of using a full weave pass technique.

Chemical and Spectrographic Analyses. Representative broken 0.505-in. diameter all-weld-metal tensile specimens prepared from the different brands and batches of E6011 electrodes were analyzed by chemical and spectrographic means in order to determine whether there were any differences in chemical constituents. Results indicate that there were no appreciable differences between the weld deposits in chemical composition except for the manganese and molybdenum content. The manganese content of the Brand C deposited weld metal was lower than that encountered in most other deposits of electrodes, whereas the molybdenum content of three different deposits was considerably higher. From an analysis of the physical properties, it was noted that the yield point and tensile strength of the Brand C tensile specimens were lower than the other brands; also their elongations were not affected appreciably by a quench time within 20 sec. This may be attributed to their lower manganese content.

Weld deposits of identical brands quenched at different times and exhibiting different types of fractures have essentially similar chemical compositions.

Metallographic Analysis of Broken 0.505-in. Diameter All-Weld-Metal Tensile Specimens. The threaded ends of typical broken tensile specimens that exhibited brittle, woody fractures with low elongations or ductile fractures with acceptable elongations were examined

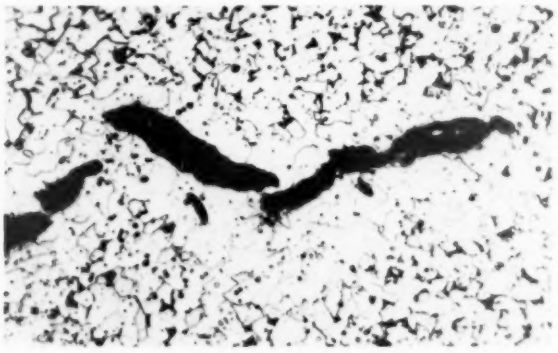
Fig. 3 Broken 0.505-in. diameter, all-weld-metal tensile specimens welded within 1 min. quench time. Partial ductile and brittle fractures

Fig. 4 Broken 0.505-in. diameter all-weld-metal tensile specimens welded within 2 min. quench time. Partial ductile and brittle fractures

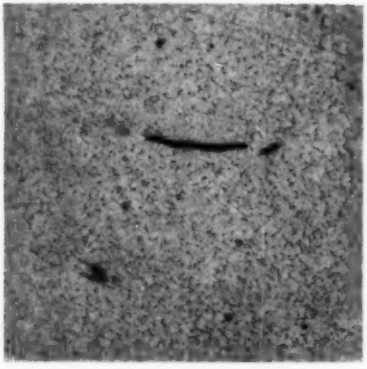
microscopically in order to detect any fundamental differences in metal structure. Sections cut along the transverse and longitudinal axes of the tensile specimens at the threaded ends were polished, etched and studied at magnifications of 100 × and 500 ×.

No unusual defects were detected in the examination of the transverse sections. Upon examination of the longitudinal sections, however, fissures somewhat similar in appearance to hydrogen flakes in forged steels were observed in those tensile specimens having brittle, woody-appearing fractures with low elongation. These fissures were below 0.010 in. in height (dimensions

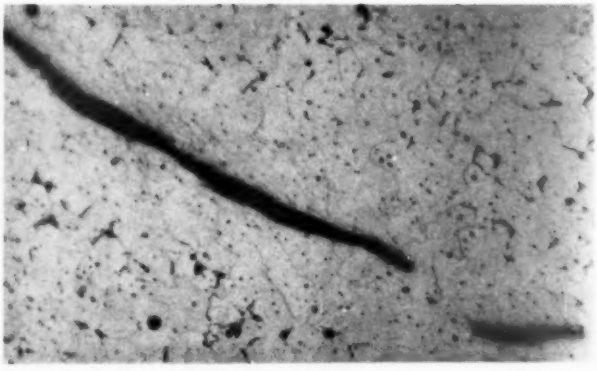
Magnification, 100 ×



Magnification, 500 ×



Magnification, 100 ×



Magnification, 500 ×

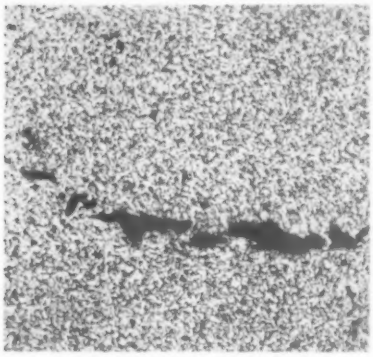
Fig. 5 Photomicrographs of typical fissures located in the finer grain zone on E6011 multipass deposits welded within 20 sec. quench time

shown on longitudinal section) whereas the fissures in flaked forged steels are usually 0.25 in. in diameter. From an examination of longitudinal micro-specimens of single beads prepared in the bead quench test indicated below, it was observed that the fissures were located, in general, at the boundaries of the columnar grains. The recrystallization and annealing of the bead that occurred in multipass welding produced no visual changes upon the location and appearance of the fissures. The location of the fissures at the boundaries of the columnar grains seems to indicate that the detected fissures are merely cross sections of microscopic fissures that are parallel to the transverse axes of the tensile specimens or weld deposits. Since the location of the fissures is predominantly transverse, their detection is difficult in transverse sections. In multipass welds, the locations of the fissures were predominantly confined to the fine grain area of the recrystallized zones although some were occasionally located in the small grains.

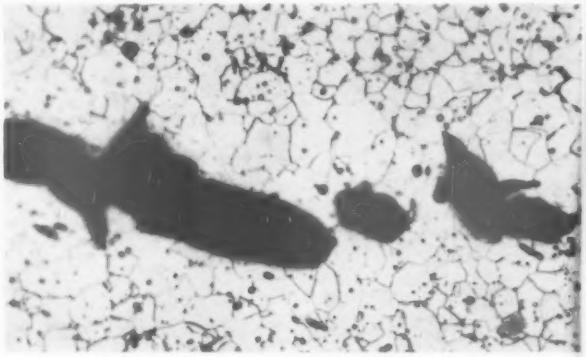
Typical photomicrographs are shown in Figs. 5 and 6 for recrystallized weld metal, and in Fig. 13 for single bead weld metal.

The results indicate that the relative number of fissures decrease as the quench time is increased for the welding of test plates with the same E6011 brand of electrode. A 2-min. quench time appears to be the transition point from a condition of very few fissures to a condition of no fissures with 3-min. or longer quench time specimens. It also appears that the presence of these fissures is related to the brittle, woody fractures accompanied by low values of elongation which are obtained with severe quench times.

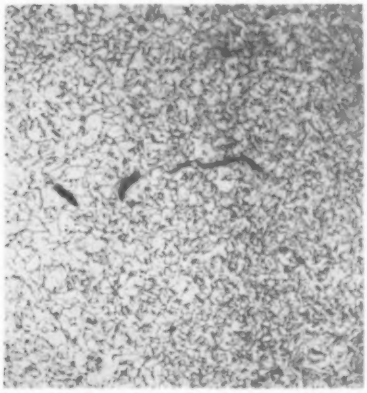
Bead Quench Test. During the metallographic analysis of the tensile specimens, it was recognized that a simple procedure to determine the transition point of the quench time beyond which no fissures are produced could conveniently be used to expedite this work. The procedure developed was to preheat a plate of 4- x 5- x $^3/_4$-in. medium steel in boiling water for 5 min. A single bead was deposited approximately $^3/_4$ in. wide along the 5-in. center line of the plate in order to simulate the "4-diameter weave" used in the preparation of physical test plates. It is to be noted that only $^3/_{16}$-in. diameter electrodes were used. The



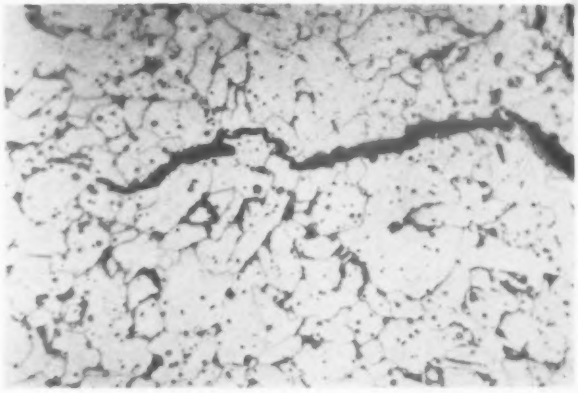
Finer Grain. Magnification, 100 ×



Finer Grain. Magnification, 500 ×



Small Grain. Magnification, 100 ×



Small Grain. Magnification, 500 ×

Fig. 6 Photomicrographs of typical fissures located in the finer and small grain zone of an E6011 multipass deposit welded within 20 sec. quench time

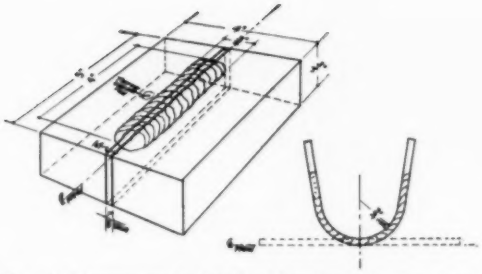


Fig. 7 Diagrammatic sketch of bend sample from bead quench test specimen

plates were then placed in the boiling water after the desired quench time had elapsed, and were removed when the excessive boiling of the water subsided. The currents and voltages used were comparable to those for the regular tensile plates. Sections were cut along the longitudinal axis of the bead and were polished, etched and examined at a magnification of 100 ×. These tests were made for E6010, E6011, E6020 and low-hydrogen types of electrodes.

Results of the bead quench tests indicate that most fissures disappear when a quench time of 3 min. is used. No fissures were detected for the low-hydrogen type of electrode used. However, this is not meant to imply that all brands of low-hydrogen type electrodes will not produce fissures under rapid quench conditions.

Evaluation of Bead Quench Test Specimens. The preliminary evaluations of the bead quench test specimens, indicated above, were based on metallographic examination of the longitudinal sections of the deposit. To expedite evaluations, the procedure shown in Fig. 7 was developed. A longitudinal slice was cut from the specimen, ground on the face through the weld center line and finished on 2/0 paper. The sample was then bent in a standard bend-test jig ($1^1/_2$ in. diameter pin).

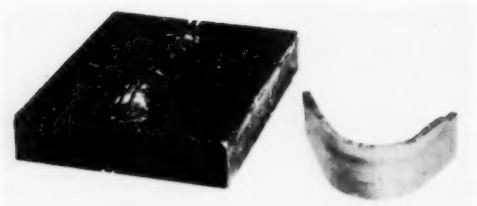


Fig. 8 Bead quench test specimens, showing position of bend sample and representative bend sample as macroetched after bending

Figure 8 shows a specimen plate as cut and a typical bend sample after macroetching. Visual examination of the etched surface readily revealed the presence of fissures, which would open slightly during the bending deformation. Check metallographic examination of the mating face (marked *M* on Fig. 7) confirmed the extent of fissures in the specimen. Typical appearances of the bend samples after macroetching, for one bead quench test specimen (H3-10) allowed to cool in air (10-min. quench) and for one specimen quenched immediately (H3-1), are shown in Figs. 9 and 10 at about 10 × magnification.

Effect of Quench Media. In order to eliminate the water, into which the bead quench test specimen is immersed after welding, as a cause of fissure formation, several samples were prepared using Brand B electrodes, under conditions which provided rapid quench effects without the use of postwelding water immersion. One procedure involved cooling the plate, prior to bead deposition, to a temperature of −50° F. No postwelding treatment, other than normal air cooling, was employed. A second procedure involved depositing the bead over a hole drilled in line with the weld and through the plate thickness, and through which water

Fig. 9 Macroetched bend sample of bead quench test specimen No. H3-10, Type E6011 electrode, 10-min. quench. 10 ×

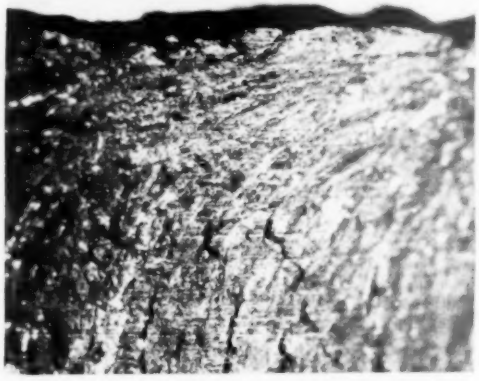
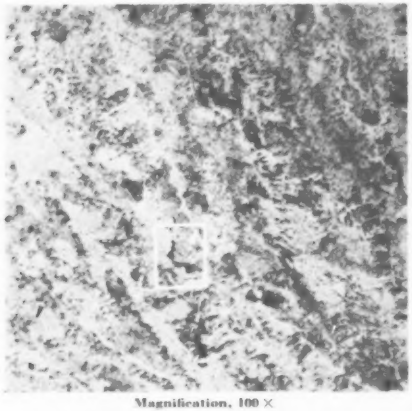


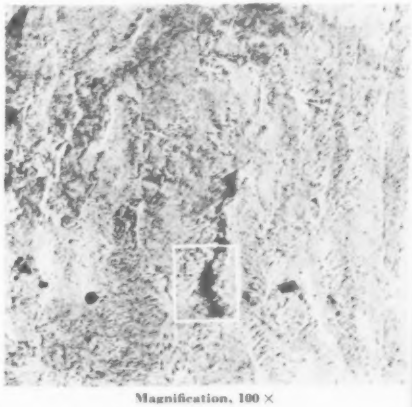
Fig. 10 Macroetched bend sample of bead quench test specimen No. H3-1, Type E6011 electrode, 20-sec. quench. 10 ×

Fig. 11 Macroetched bend sample of bead quench test specimen No. H3-50, Type E6011 electrode. Plate precooled to −50° F.; no postwelding treatment. 10 ×

Fig. 12 Macroetched bend sample of bead quench test specimen No. H3-WR, Type E6011 electrode. Plate cooled by water through internal bored hole; no postwelding treatment. 10 ×



Magnification, 100 ×



Magnification, 100 ×

Area 1 of above. 500 ×

Area 1 of above. 500 ×

Fig. 13 Microstructure of weld deposit, longitudinal section, bead quench test bend specimen No. H3-WR, Type E6011 electrode. Plate cooled by water through internal bored hole; no postwelding treatment. Nital etch

at about 60° F. was flowing. Similarly, no postwelding treatment was used.

The appearances of the bend specimens (H3-50 and H3-WR, respectively) are shown in Figs. 11 and 12. The extent of fissure formation is apparent.

A duplicate bead quench test bend specimen, water-cooled through an internally bored hole, was examined metallographically. The structures observed are shown in Fig. 13, to which previous reference has been made. The fissures predominantly are oriented along the boundaries of the columnar grains, and appear to be associated with unidentified inclusions.

The etched specimen was then bent to a radius of about 1 in. and re-examined under the microscope without further preparation. The appearance of the distorted surface is shown in the several photomicrographs of Fig. 14. The embrittlement of the weld metal is readily apparent from the nature and frequency of the fissures. It may be noted that many of these fissures developed in areas shown in the photomicrographs of Fig. 13, but their unstressed appearance was so closely delineated with the etched structure as to be considered part of it.

It was then decided to determine whether the quenching effect of the mass of a large steel billet was capable of producing fissures in welded single beads deposited thereon. A 12- x 12- x 18-in. medium steel billet was procured and single beads were deposited on the 12- x 12-in. face of the billet at room temperature. The beads were permitted to cool to room temperature without an external quenching medium. Electrodes of the same size and type specified in the preceding test were used to deposit the beads. After the beads were sectioned, polished and etched, they were examined at a magnification of 100 ×. Fissures were detected in many of the different types of electrode deposits.

Effect of Temperature and Cooling Rates. In view of the production of fissures in the weld-metal deposit by rapid cooling rates, it was decided to investigate the

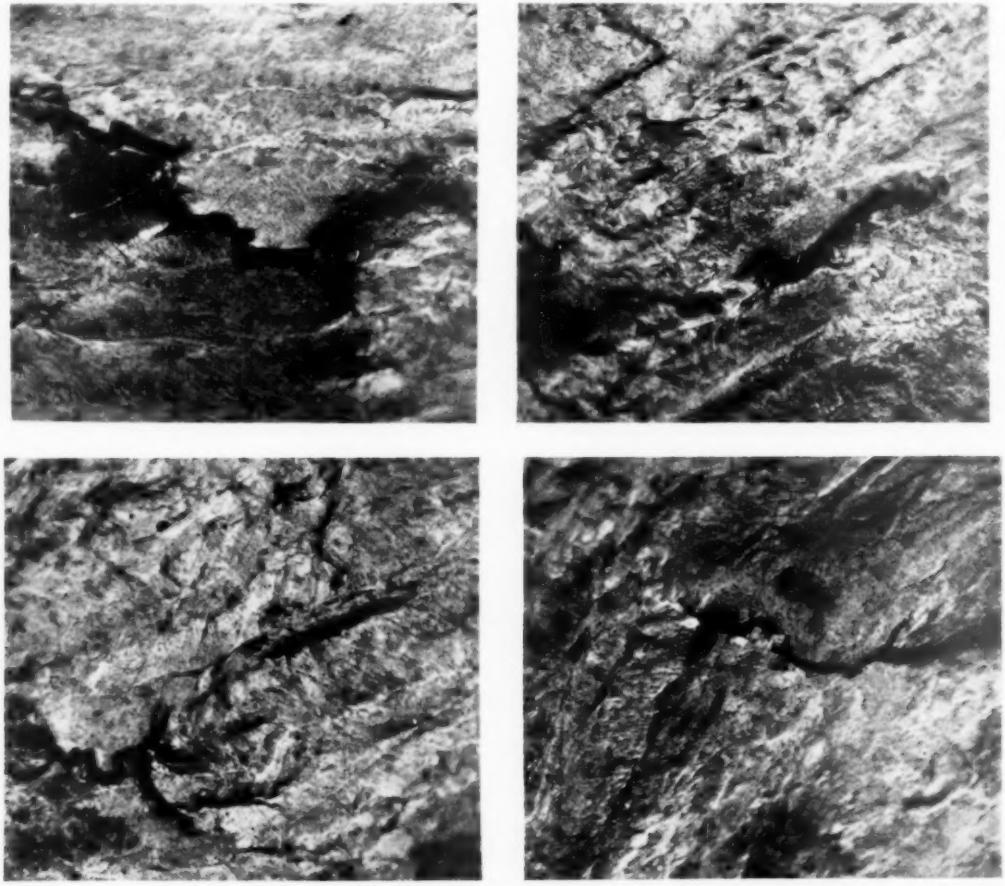


Fig. 14 Microstructure of weld deposit, longitudinal section, surface of bead quench test bend specimen No. H3-WR of Fig. 13 after bending to approximately 1-in. radius. 100 ×

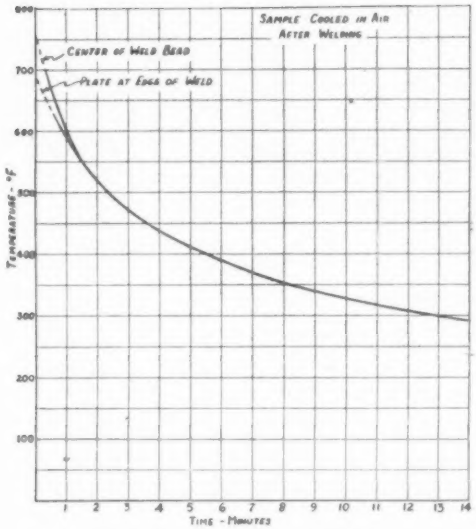


Fig. 15 Cooling curve of bead quench test specimen

effect of temperature and rates of cooling on fissure formation. The normal rate of cooling of a typical bead quench test specimen is shown in Fig. 15. Temperatures were determined using 31 gage wire iron-constantan thermocouples and an L and N potentiometer. A small weld pad placed adjacent to the bead edge and ground smooth assured rapid response of the thermocouple to the plate temperature. The time indicated on Fig. 15 represents intervals after the completion of the entire length of the bead. It may be noted that the center of the weld bead (mid-point of the full length) and the pad adjacent to the bead attain equivalent temperatures within 2-min. after the entire bead has been welded.

Several series of bead quench test specimens were prepared using Brand B electrodes in order to determine the effect of specimen temperature prior to quenching on fissure formation. The first series involved preheating of the plate to various temperatures, depositing the weld bead and quenching in boiling water immediately after welding. The second series involved holding the welded specimen, after completion of welding, at its final temperature of about 700° F. for varying time intervals. It was noted that, in general, variations in treatments have little, if any, effect on the extent of fissure formation, provided quenching of the specimen occurs within a 2-to-3-min. period after completion of welding. In this respect the above results confirm the time interval for fissure formation previously indicated for this brand of electrode (Brand B).

A final series of specimens was prepared in order to check not only the effect of quenching, from the elevated temperatures, on fissure production, but also to check the validity of assuming that only dissolved hydrogen primarily was responsible for these fissures. This series involved welding, cooling, reheating to elevated temperatures and quenching. It was noted that specimens H3-1R and H3-3R duplicate results obtained previously for this brand of electrode. Increasing the time interval between completion of welding and quenching, beyond 3 min. under normal rates of cooling, or for 3 min. at an elevated temperature, practically eliminates the formation of fissures. Quenching, in itself, from the elevated temperature does not produce fissures in weld metal deposit from which an apparently significant amount of originally dissolved hydrogen has been evolved. The effect of increased time intervals is to allow evolution of dissolved hydrogen to occur, and the shorter time at the elevated temperature is consistent with the greater rate of evolution expected.

DISCUSSION

From the results described herein, it is seen that when rapid quench conditions are used in the welding of physical test plates, tensile specimens are produced that are characterized by brittle, woody appearing fractures with low values of elongation. These tensile specimens also contain microscopic fissures similar to hydrogen flakes. The fissures appear to have directional properties, i.e., their maximum dimensions (area) are parallel to the transverse axis of the tensile specimens or weld deposits. Due to the fissures' directional properties, tensile specimens machined transverse to the axis of a weld deposit will not exhibit brittle, woody fractures.

There appears to be a relationship between quench time, value of elongation, type of fracture and the presence of fissures. As the quench time is increased, the value of elongation increases, the type of fracture changes from a brittle, woody type to a ductile type, and the relative number of fissures decrease to a point of no fissures. Yet, the presence of fissures does not necessarily indicate that tensile specimens containing them will have values of low elongation with brittle, woody type of fracture. This is shown in the testing of Brand C electrodes. Acceptable values of elongation and ductile type of fractures were obtained when physical plates were welded within a 20-sec. quench time, but fissures were detected in the deposit. On examination of the chemical analysis, it was noted that the manganese content is low in this brand of electrode deposit. Hence, the chemical composition also enters as a factor to be considered in predicting values of low elongation when a test plate has had a rapid quench.

The several exploratory tests described above, using the bead quench test specimen, appear to offer some explanation of the phenomenon noted. The general characteristics of the observed fissures and the factors favoring their production are considered as indirect but sufficient evidence for assuming hydrogen to be the responsible agent. Quenching from the moderately elevated temperature of about 700° F. does not produce

fissures in weld metal in which dissolved hydrogen either is a minimum quantity (as that from a low-hydrogen type electrode), or has been permitted to escape normally by delaying the operation (increased quench time). In view of the production of fissures in weld metal cooled rapidly in the absence of any external source of hydrogen, it is obvious that only such hydrogen as may be derived from the electrode coating during welding is involved.

The results also indicate that one critical factor appears to be the amount of hydrogen in the weld deposit prior to quenching. In a normal E6011 type electrode, about 0.30 cc. hydrogen per gram of weld metal may be present on completion of welding. Low-hydrogen type electrodes may produce welds containing about 0.10 cc. hydrogen per gram of deposit. Between these approximate quantities, which represent the extremes in fissure production of rapidly quenched specimens, must be a critical content of hydrogen below which no fissures will be formed.

SUMMARY

The results of this investigation may be summarized as follows:

(*a*) A quench time of 1 min. causes a marked reduction in the elongation of all-weld-metal tensile specimens of the majority of $^3/_{16}$-in. diameter E6011 electrodes tested.

(*b*) A 3-min. quench time appears to be the minimum time required for the majority of the $^3/_{16}$-in. diameter E6011 electrodes tested to exhibit the expected minimum elongation of 22%; some brands of electrodes require a still longer quench time.

(*c*) All brands of $^3/_{16}$-in. diameter electrodes tested produce tensile specimens with elongations of 22% and above when tested with a 10-min. quench time.

(*d*) Both full weave and "4-diameter split-weave" pass techniques when used with a quench time within 1 min. show a marked reduction in the elongation of the resulting all-weld-metal tensile specimens of $^3/_{16}$-in. diameter E6011 electrodes.

(*e*) Broken tensile specimens of E6011 physical test plates welded with a rapid quench have fissures somewhat similar in appearance to hydrogen flakes, in forged steel. However, as opposed to hydrogen flakes, these fissures appear to have directional properties, i.e., the maximum dimensions (area) of the fissure are parallel to the transverse axis of the tensile specimen or weld deposit. The fissures were only detected in longitudinal sections of the weld deposits, which show their cross sections. The fissures seem to disappear when a quench time of 3 min. or longer is used.

(*f*) Fissures are produced in E6011 electrode deposits by rapid cooling of weld metal containing more than some critical amount of dissolved hydrogen. These fissures generally are interdendritic in the columnar structure of the single bead; their orientation and form are not changed by recrystallization due to heat effects of additional weld passes. Thus it may reasonably be assumed that stress-relieving of a rapid quenched specimen would not eliminate the fissures.

(*g*) Increase in the quench time (interval between completion of weld and quenching) decreases extent of fissure formation regardless of subsequent rapid cooling of the weld metal deposit. The effect of such delay in quenching appears to be in reducing the amount of retained dissolved hydrogen in the weld metal.

It is apparent that several questions of primary importance in the phenomenon of fissure formation are yet to be answered. Although the assumption has been made that hydrogen is the responsible agent, no direct evidence for this is at hand. The peculiar orientation of the fissures transverse to the axis of the weld may be correlated with stress conditions produced on quenching or with the mechanism of weld metal deposition; neither phase has been investigated at this time. Further a quantitative determination of the amounts of dissolved hydrogen might be of interest, in order to design electrodes or to develop postwelding conditions, especially for field welding operations, which would be effective in eliminating fissure formation.

The importance of the phenomenon cannot be ignored. Although this investigation was devoted to laboratory phases alone, it can be appreciated that field conditions might produce similar results in weld metal deposited on cold plates or on heavy metal sections. Although the presence and/or effect of such fissures has not been reported, the author feels it is reasonable to assume that they may have been involved in some instances of weld failures, acting as so-called incipient notches.

ACKNOWLEDGMENT

The author wishes to acknowledge the cooperation and assistance of V. DiGiglio, H. Nagler and I. L. Stern, Welding Engineers in the Welding Section, Material Laboratory, New York Naval Shipyard, in securing the data and in the preparation of this paper. Prepublication comments and advice from C. A. Loomis, Bureau of Ships, Navy Department, are sincerely noted. Permission by the Navy Department to publish this work is appreciated.

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Composition and Property Variation of Two Steels

Progress Report No. 2 on the effect of fabrication processes on steels used in pressure vessels. Data is given on the within heat variation of composition and properties of the rimmed and aluminum-killed steels being used in the Pressure Vessel Research Program

by C. J. Osborn, A. F. Scotchbrook, R. D. Stout and B. G. Johnston

FOREWORD

THIS is the second of a series of reports (see reference 10) describing the results of work performed at Lehigh University for the Fabrication Division of the Pressure Vessel Research Committee of The Welding Research Council. The underlying purpose of the work is to study the effect of fabrication processes involving plastic strain with or without subsequent heat treatment, welding or strain aging, on the relative tendency of various steels toward brittle failure at low temperature. Two steels, one rimmed and the other aluminum-killed, each in two plate thicknesses ($^5/_8$ and $1^1/_4$ in.), were obtained for the initial part of the project.

This report presents the results of a series of tests suggested by the Materials Division of the Pressure Vessel Research Committee to determine the variation of composition and mechanical properties within the two heats of steel being used in the main investigation. Since the steels investigated are being used for other research programs sponsored by the Pressure Vessel Research Committee, it is felt that these results should be published.

INTRODUCTION

The tendency of a steel to fail in a brittle fashion is of tremendous practical importance in engineering structures and much is already known concerning the factors which govern this tendency. It is known, for example, that chemical composition exerts an important influence on the mode of failure and that, other things being equal, the transition temperature of a steel rises with an increase in its carbon content.[1] Other elements, notably manganese[2] and nitrogen,[3] are also considered by some to affect the transition temperature. The influence of chemical composition on strength and ductility is also well known.

However, it is also known that within a single heat of steel, and even within a single ingot or plate, there occur marked differences in composition. These arise both from the different times of holding in the ladle before pouring successive ingots, and from segregation and rimming effects during solidification of ingots. Since such composition differences may well be of appreciable magnitude, their distribution and their influence on fracture characteristics and other physical properties become matters of considerable importance to the engineer.

The present investigation was performed on two heats of steel whose prior histories were completely known, in order to obtain information on these and allied questions. One heat, aluminum-killed, had been supplied to A.S.T.M. Specification A-201 and the other, a rimmed steel, to A.S.T.M. Specification A-70. The former, an aluminum-killed heat, had been cast into 9 big-end-up hot-topped ingots, 34 x 66 in., each weighing 50,450 lb.* The Pressure Vessel Research Committee obtained plates from ingots numbered 1, 2, 3, 4, 5 and 9; ingots 1 and 3 were rolled to $^5/_8$ in. thickness, and the others to $1^1/_4$ in. thickness. The top halves of ingots 1, 2 and 4 were mill-normalized. Ingots 1, 3, 4 and 9 were used in the present investigation. The rimmed steel heat had been cast into four groups of bottom-poured ingots. Each ingot was rolled into one plate and cut to 72 x 288 in., the six $^5/_8$-in. plates for the Pressure Vessel Research Committee coming from the first group and the six $1^1/_4$-in. plates from the third. One plate of each thickness was used in this investigation.

The following tests were performed at selected places within the chosen ingots:

1. Chemical Analyses.
2. Macroscopic Inspection: controlled deep etch; sulphur prints.
3. Microscopic Inspection: as-rolled metallographic; inclusion count; grain-coarsening tests; McQuaid-Ehn tests.

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* Other particulars concerning the mill histories of both heats are given in an Appendix of this report.

Table 1—Chemical Composition of A-201 Ingots

	C	Mn	P	S	Si	Cu	Ni	Cr	W	V	Mo	Al	Al_2O_3	N_2
Ingot 1, rolled to 5/8 in.														
Top center	0.17	0.57	0.020	0.021	0.21	0.06	0.05	0.04	0.04	0.02	0.01	0.041	0.004	0.005
Middle center	0.17	0.55	0.020	0.022	0.21	0.06	0.05	0.04	0.04	0.02	0.01	0.041	0.003	0.005
Bottom center	0.15	0.54	0.018	0.020	0.20	0.05	0.05	0.04	0.04	0.02	0.01	0.038	0.004	0.004
Ingot 4, rolled to 1 1/4 in.														
Top center	0.18	0.55	0.020	0.022	0.20	0.06	0.05	0.04	0.04	0.02	0.01	0.045	0.003	0.004
Middle center	0.15	0.55	0.020	0.019	0.20	0.07	0.06	0.05	0.04	0.02	0.01	0.041	0.006	0.004
Bottom center	0.14	0.53	0.019	0.018	0.20	0.06	0.05	0.04	0.04	0.02	0.01	0.040	0.003	0.004
Ingot 9, rolled to 1 1/4 in.														
Top edge	0.16	0.53	0.014	0.023	0.19	0.06	0.05	0.04	0.04	0.02	0.01	0.038	0.004	0.004
Top center	0.16	0.54	0.022	0.026	0.19	0.07	0.06	0.05	0.04	0.02	0.01	0.027	0.002	0.003
Middle edge	0.17	0.55	0.014	0.023	0.18	0.06	0.05	0.04	0.04	0.02	0.01	0.034	0.004	0.004
Middle center	0.15	0.53	0.020	0.025	0.19	0.08	0.05	0.04	0.04	0.02	0.01	0.026	0.002	0.003
Bottom center	0.15	0.54	0.019	0.023	0.18	0.08	0.06	0.05	0.04	0.02	0.01	0.042	0.005	0.004

4. Mechanical Tests: strip tensiles; 0.505-in. tensiles; Brinell hardness; Charpy keyhole specimens, single and double width.

Each of these will be discussed individually.

1. CHEMICAL COMPOSITION

The distribution of alloying elements and impurities in killed- and rimmed-steel ingots has been investigated at considerable length by the Iron and Steel Institute, Committee on the Heterogeneity of Steel Ingots.[4–9]

In the present investigation, samples for chemical analysis were taken from the A-201 ingots 1, 4 and 9 at the top, middle and bottom center, and from ingot 9 at the top and middle edge; also from one small and one large A-70 ingot at the top, middle and bottom center, and top and bottom edge.

The results for the A-201 (Al-killed) steel are given in Table 1. The following observations may be made:

1. Concerning composition differences from ingot to ingot within the heat, the last ingot (No. 9) is slightly lower in carbon, silicon, aluminum, alumina and nitrogen than the two earlier ingots, and slightly higher in sulphur and copper. Manganese, phosphorus, nickel, chromium, tungsten, vanadium and molybdenum are approximately the same in all ingots. The decreasing carbon, silicon and aluminum contents probably result from oxidation in the ladle. The increasing sulphur content may be due to density segregation of sulphides in the ladle.
2. On the vertical center line of each ingot carbon, manganese, phosphorus, sulphur and silicon decrease slightly from top to bottom. In ingot 9, aluminum increases markedly from top to bottom.
3. From the limited results available (ingot No. 9) it appears that at least sulphur and phosphorus increase from the edge to center of the ingot. The British investigators[5, 6] found phosphorus segregation of the order shown in Table 1 only in ingots much larger than ingot No. 9. Otherwise the magnitude and pattern of segregation is much as indicated by Hatfield.[4, 5, 6] Aluminum, alumina and nitrogen decreased from edge to center.
4. The maximum and minimum values of carbon content recorded are at the top and bottom center, respectively, of ingot No. 4: the range is 0.14 to 0.18% C.

Results for the A-70 (rimmed steel) are given in Table 2. Significant features are:

1. The group of larger ingots rolled to 1 1/4 in. was cast some 10 minutes after the group of smaller ingots. The average compositions of the two ingots were not very different except with regard to aluminum which was appreciably higher in the large ingot owing to a further addition of aluminum to reduce gassing in this group.
2. Manganese, phosphorus, silicon, copper, nickel, chromium, tungsten, vanadium, molybdenum

Table 2—Chemical Composition of A-70 Ingots

	C	Mn	P	S	Si	Cu	Ni	Cr	W	V	Mo	Al	Al_2O_3	N_2
Ingot 2, rolled to 1 1/4 in.														
Top edge	0.22	0.36	0.020	0.034	0.02	0.14	0.10	0.04	0.04	0.02	0.01	0.017	0.004	0.004
Top center	0.23	0.35	0.017	0.032	0.02	0.15	0.10	0.04	0.04	0.02	0.01	0.007	0.005	0.005
Middle center	0.20	0.35	0.018	0.028	0.02	0.14	0.10	0.05	0.04	0.02	0.01	0.021	0.003	0.003
Bottom edge	0.14	0.34	0.018	0.020	0.01	0.14	0.09	0.04	0.04	0.02	0.01	0.019	0.002	0.003
Bottom center	0.18	0.34	0.018	0.028	0.02	0.15	0.09	0.04	0.04	0.02	0.01	0.038	0.003	0.003
Ingot 7, rolled to 5/8 in.														
Top edge	0.14	0.36	0.018	0.017	0.02	0.12	0.09	0.04	0.04	0.02	0.01	0.012	0.002	0.004
Top center	0.25	0.37	0.020	0.035	0.02	0.14	0.10	0.04	0.04	0.02	0.01	0.005	0.003	0.005
Middle center	0.22	0.37	0.019	0.028	0.02	0.12	0.10	0.04	0.04	0.02	0.01	0.010	0.002	0.004
Bottom edge	0.18	0.35	0.020	0.021	0.02	0.12	0.09	0.04	0.04	0.02	0.01	0.012	0.002	0.003
Bottom center	0.19	0.36	0.019	0.020	0.02	0.13	0.10	0.04	0.04	0.02	0.01	0.028	0.002	0.003

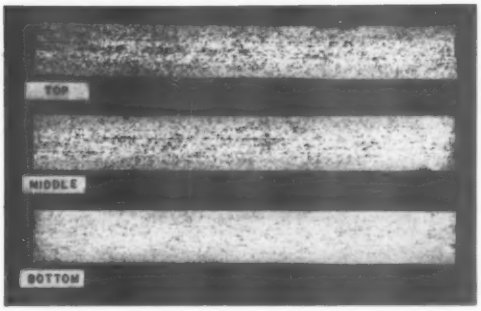

Fig. 1 Sulphur prints of A-201, Ingot 9

and nitrogen segregated very little in either of the ingots examined.

3. Carbon, sulphur and alumina contents were appreciably higher at the top center of the ingot than elsewhere, while the aluminum content was a minimum at this point.
4. The maximum and minimum values of carbon content recorded occurred at the top of the small ingot (No. 7), the range being 0.14 to 0.25%. This is a greater range than was observed in the A-201 steel but is not inconsistent with previous reports on rimmed steel ingots.[6]

II. MACROSCOPIC INSPECTION

A deep etch and a sulphur print were made on plate samples from the top, middle and bottom center of A-201 ingots 1, 4, 9 and A-70 ingots 2 and 7. All samples were longitudinal.

The sulphur prints were made by applying Velox F-3 photographic paper soaked in 4% sulphuric acid to a ground surface for 10 minutes. Copies of some of the prints are shown in Figs. 1 and 2. In all cases it was clear that sulphur had segregated to the top of the ingot. The low sulphur content of the rim as seen in Fig. 2 was very marked.

The deep etch treatment consisted of 30 minutes of 50% hydrochloric acid at 150° F. Some of the results are shown in Figs. 3 and 4. Here the greater cleanliness

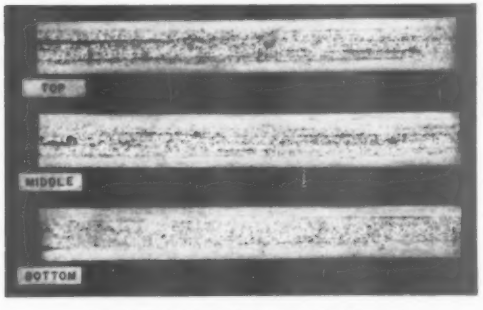

Fig. 2 Sulphur prints of A-70, Ingot 2

at the bottom of the ingots is evident from the less severe attack during etching. The dirt or other unsoundness discovered by the deep etch appears coarser and less uniform in the A-70 ingot than in the A-201. The controlled etch did not show any significant difference between ingots of the same heat.

III. MICROSCOPIC INSPECTION

Using samples from the same locations as the macrospecimens, inclusion counts were first made on the unetched specimens according to A.S.T.M. Specification E45–46T, Method A. The predominant type of inclusion in both steels was the globular oxide. There was no great difference between the two steels in regard to the number and distribution of nonmetallic inclusions

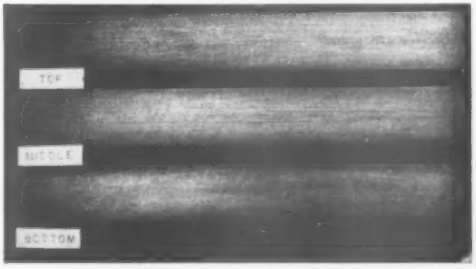

Fig. 3 Deep-etch specimens from A-201, Ingot 9

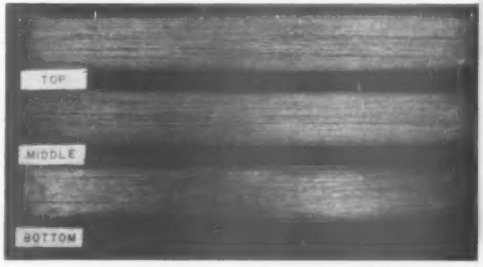

Fig. 4 Deep-etch specimens from A-70, Ingot 2

and within each heat there seemed to be little variation from ingot to ingot.

The microstructures at the top, middle and bottom center of A-201 ingots 1 and 9 are shown in Figs. 5 and 6. The very fine grain size produced by mill-normalizing is noteworthy in the top of ingot 1. The as-rolled samples of $^5/_8$-in. plate from ingot 1 have a finer grain size than the samples of $1^1/_4$-in. plate taken from the corresponding position in ingot 9.

Figure 7 shows microstructures at the top, middle and bottom center of A-70 ingot 2. It is evident that the carbon content increased from the bottom to the top of the ingot; again the $^5/_8$-in. plate had a finer grain size than the $1^1/_4$-in. plate.

The grain-coarsening characteristics of the two steels were studied by two methods on samples from

the middle of A-201 ingots 1 and 9, and A-70 ingots 2 and 7; i.e., one $^5/_8$- and one $1^1/_4$-in. plate from each heat.

McQuaid-Ehn tests were made at 1675° F. in accordance with A.S.T.M. Specification E19–46 and the following results were obtained:

	McQuaid-Ehn grain size
A-201, $^5/_8$-in. plate (Ingot 1)	8
A-201, $1^1/_4$-in. plate (Ingot 9)	8
A-70, $^5/_8$-in. plate (Ingot 7)	3
A-70, $1^1/_4$-in. plate (Ingot 2)	4

In addition to the standard McQuaid-Ehn test, a series of grain-coarsening tests was run on the same four plates by holding small samples for one hour at each of the following temperatures: 1350, 1500, 1650, 1800, 1950 and 2100° F. Samples at the four higher temperatures were transferred to another furnace at 1500° F. for an hour before water quenching; those at 1350 and 1500° F. were water quenched directly. All quenched samples were tempered at 800° F. This procedure gave microstructures in which the austenitic grain size was outlined by ferrite in a dark matrix of tempered martensite.

Table 3—Grain-Coarsening Results

Heated 1 hr. at temp., ° F.	*A.S.T.M. Grain Size No.*			
	$^5/_8$*-in. A-201*	$1^1/_4$*-in. A-201*	$^5/_8$*-in. A-70*	$1^1/_4$*-in. A-70*
1350	8	7	8	7
1500	7	7	7	7
1650	7	7	7	7
1800	7	6	7 + 3	7 + 3
1950	7 + 3	1 — 3	3	3
2100	3	1 — 3	2 — 3	2 — 3

From the results (Table 3) of these tests it can be seen that both the rimmed and the aluminum-killed steels have a sharp coarsening temperature or temperature range. In the rimmed steel this is about 1800° F., while in the killed steel it is slightly higher, although not above 1950° F. A sharp coarsening temperature or temperature range is characteristic of steels containing aluminum or certain other grain refining elements such as vanadium and titanium; the heat records and

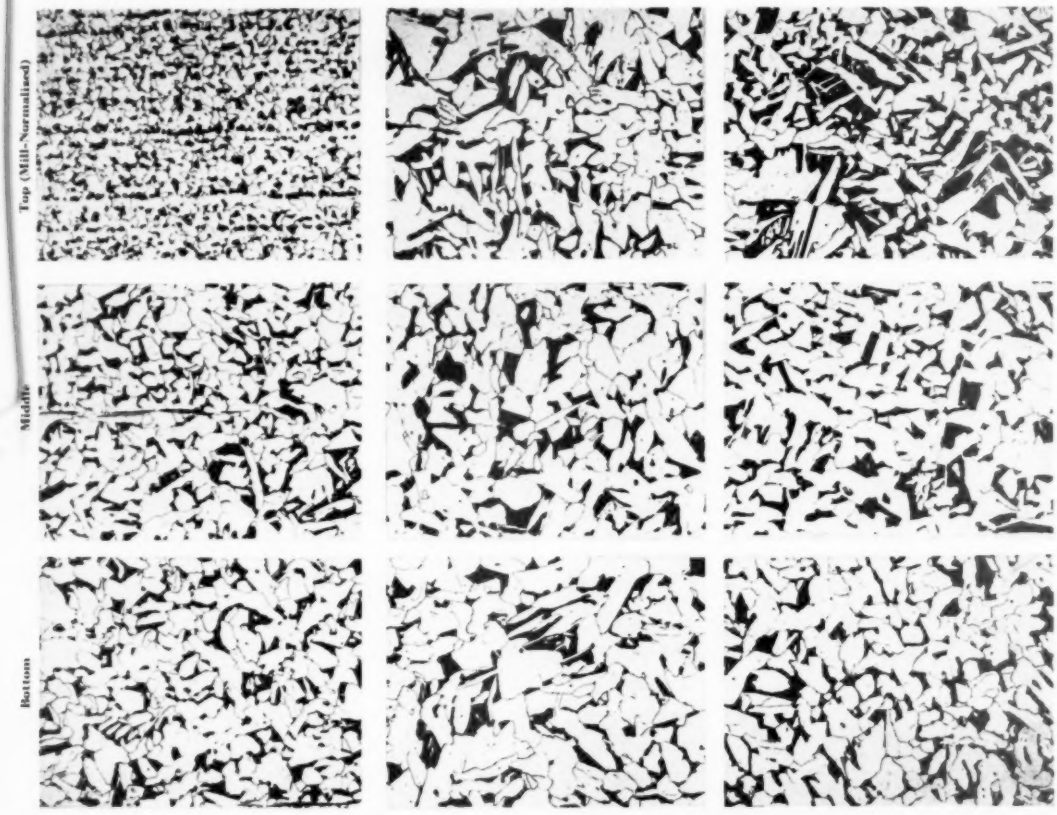

Fig. 5 A-201, Ingot 1, rolled to $^5/_8$ in. thickness. Micrographs at 100 ×, Nital etch

Fig. 6 A-201, Ingot 9, rolled to $1^1/_4$ in. thickness. Micrographs at 100 ×, Nital etch

Fig. 7 A-70, Ingot 2, rolled to $1^1/_4$ in. thickness. Micrographs at 100 ×, Nital etch

Table 4—Tensile Properties of A-201 Plates as Determined by Strip Tensile Tests*

Ingot	Gage, In.	Position	Orientation to rolling direction	Upper yield point, psi.	Lower yield point, psi.	Nominal maximum, psi.	Per cent elongation (in 8 in.)	Per cent reduction of area
1	5/8	Top**	Parallel	37,100	36,850	60,250	33.8	59.6
1	5/8	Top	Transverse	38,400	38,000	59,500	30.1	58.5
1	5/8	Middle	Parallel	35,600	35,100	60,600	30.5	56.9
1	5/8	Middle	Transverse	36,000	35,800	60,600	31.2	55.8
1	5/8	Bottom	Parallel	34,800	34,400	58,700	32.2	66.4
1	5/8	Bottom	Transverse	35,500	34,600	58,750	31.7	58.6
3	5/8	Top	Parallel	36,900	35,750	61,800	29.8	58.8
3	5/8	Top	Transverse	37,300	36,700	61,650	29.0	57.4
3	5/8	Middle	Parallel	35,900	35,600	60,750	32.8	64.1
3	5/8	Middle	Transverse	35,800	35,400	60,300	. .	54.9
3	5/8	Bottom	Parallel	36,100	35,700	59,600	28.9	65.1
3	5/8	Bottom	Transverse	35,300	34,900	58,600	31.6	59.9
4	1 1/4	Top**	Parallel	32,800	32,600	59,600	30.5	60.9
4	1 1/4	Top	Transverse	32,600	32,300	59,200	31.8	54.1
4	1 1/4	Middle	Parallel	31,800	31,400	59,500	34.9	61.8
4	1 1/4	Middle	Transverse	32,300	31,800	59,100	32.9	53.6
4	1 1/4	Bottom	Parallel	31,400	31,000	56,700	35.1	64.7
4	1 1/4	Bottom	Transverse	31,600	30,700	56,400	33.1	58.8
9	1 1/4	Top	Parallel	31,500	31,300	59,700	32.6	57.1
9	1 1/4	Top	Transverse	32,500	31,200	59,800	31.0	49.2
9	1 1/4	Middle	Parallel	32,500	31,300	59,800	29.7	60.0
9	1 1/4	Middle	Transverse	31,700	31,200	59,500	.	51.1
9	1 1/4	Bottom	Parallel	30,600	29,900	57,300	35.0	63.2
9	1 1/4	Bottom	Transverse	29,900	29,100	55,400	34.5	55.5

* Results are average of duplicate tests.
** Normalized.

chemical analyses show that aluminum was added to both of these steels.

It is noteworthy that the long holding time (8 hr.) at 1675° F. in the McQuaid-Ehn test caused the rimmed steel to coarsen, so that this test indicated different results for the two steels. On the other hand, the grain coarsening results in Table 3 do not indicate such a marked difference.

IV. MECHANICAL TESTS

A. Strip Tensile Tests

Using the A.S.T.M. standard rectangular tensile testpiece (for example, see Specification A-201-46) the tensile properties were investigated at the following locations within the two heats:

A-201 (Al-killed steel)—Ingots 1, 3, 4 and 9 at the top, middle and bottom center.

A-70 (rimmed steel)—Ingots 2 and 7 at the top, middle and bottom center.

Duplicate specimens were tested both parallel and transverse to the rolling direction and the average results of these duplicate tests are given in Tables 4 and 5. Some conclusions may be drawn from these results.

(1) The ductility, as shown by the per cent reduction of area, was invariably less in the transverse specimens than in the parallel specimens from the same location; this difference seemed greater in the case of the A-201 than the A-70 steel.

(2) Although the plates were fairly uniform, there was a general increase in ductility and decrease in strength from the top to bottom of all ingots.

(3) As expected from the greater cooling rates following rolling, the 5/8-in. plates showed appreciably higher yield points and slightly higher

Table 5—Tensile Properties of A-70 Plates as Determined by Strip Tensile Tests*

Ingot	Gage, In.	Position	Orientation to rolling direction	Upper yield point, psi.	Lower yield point, psi.	Nominal maximum, psi.	Per cent elongation (in 8 in.)	Per cent reduction of area
7	5/8	Top	Parallel	35,600	34,200	61,000	30.5	56.3
7	5/8	Top	Transverse	35,900	35,500	60,800	27.2	54.5
7	5/8	Middle	Parallel	34,000	33,300	58,400	30.7	59.3
7	5/8	Middle	Transverse	33,600	33,500	58,000	29.3	55.8
7	5/8	Bottom	Parallel	32,200	30,400	55,600	31.0	61.4
7	5/8	Bottom	Transverse	32,500	32,200	56,100	28.1	58.1
2	1 1/4	Top	Parallel	29,500	27,800	57,500	31.5	56.3
2	1 1/4	Top	Transverse	29,100	28,000	57,200	30.8	52.5
2	1 1/4	Middle	Parallel	28,800	27,300	55,700	33.2	55.8
2	1 1/4	Middle	Transverse	27,700	27,200	55,000	29.4	53.5
2	1 1/4	Bottom	Parallel	27,200	25,500	53,400	33.6	58.1
2	1 1/4	Bottom	Transverse	26,700	26,300	53,100	33.6	55.8

* Results are average of duplicate tests.

strength than 1¼-in. plates from the same heat.

(4) Mill normalizing caused no significant change in the tensile properties of the A-201 plates.

B. Tensile Tests on 0.505-in. Bars

Some additional information on the tensile properties of the two steels was obtained from standard 0.505-in. diameter bar specimens. Duplicate specimens oriented parallel and transverse to the rolling direction were taken from the top edge and center, middle edge and center, and bottom center of ingot 9 and the top and bottom center of ingot 2. In addition to measurements of ductility, the following values were recorded:

$$\text{Nominal Yield Point} = \frac{\text{Yield Load}}{\text{Original Area}}$$

$$\text{Nominal Maximum Stress} = \frac{\text{Maximum Load}}{\text{Original Area}}$$

$$\text{Nominal Breaking Stress} = \frac{\text{Breaking Load}}{\text{Original Area}}$$

$$\text{True Breaking Stress} = \frac{\text{Breaking Load}}{\text{Area at Breaking}}$$

These results lead to essentially the same conclusions as did the strip tensile results. In these conclusions, changes in ductility are expressed as changes in numerical test values.

(1) The ductility as expressed by per cent elongation and per cent reduction in area was approximately 5% higher in parallel than in transverse specimens. In the case of A-201 material, the yield point was about 2500 psi. higher for the longitudinal specimens, while the A-70 specimens showed no significant difference with orientation. Nominal breaking stress was about 5000 psi. lower in the parallel specimens for the A-201 material and about 1300 for the A-70 material. The true breaking stress averaged about 8500 psi. higher for parallel specimens. The nominal maximum stress did not vary much with orientation.

(2) In both ingots from top to bottom there was a general increase in ductility of about 5% and decrease in strength of about 5000 psi. for the nominal maximum stress. From center to edge of the A-201 ingot the ductility increased about 1.5% and the nominal maximum stress decreased about 1000 psi. These trends are consistent with the chemical segregation reported earlier.

Mill Test Reports. Comparing laboratory data with the tensile results given in the mill test reports, the discrepancy between yield points measured at the laboratory and at the mill was very striking. The slower loading rate used in the research laboratory, 0.006 in. per minute crosshead speed up to yield point for 0.505-in. specimens, determined a yield point sometimes as much as 10,000 psi. lower than that determined at the mill. This divergence is well known and it should be remembered when the possibility of increasing design stresses is considered.

C. Brinell Hardness

The Brinell hardness was determined at the same locations as the strip tensile survey, using a 3000 kg. load

Table 6—Charpy Transition Temperatures (° F.) at Various Locations According to Three Criteria

	Single width specimen			*Double width specimen*		
	Energy	*Cleavage, %*	*Contraction, %*	*Energy*	*Cleavage, %*	*Contraction, %*
			A-201 Steel (Aluminum-killed)			
Ingot 1, ⅝ In.						
Top*	−80	−52	−92	...	...	...
Middle	−50		−50	...	...	...
Bottom	−60	−18	−52	...	...	...
Ingot 3, ⅝ In.						
Top	−61	−13	−62	...	...	...
Middle	−61	−33	−66	...	...	...
Bottom	−70	−42	−69	...	...	...
Ingot 4, 1¼ In.						
Top*	−47	−28	−44	−29	−19	−35
Middle	−22	+12	−27	−17	+20	−17
Bottom	−35	−10	−38	−17	+14	−32
Ingot 9, 1¼ In.						
Top	−25	+25	−26	+ 2	+42	− 7
Middle	−33	− 8	−38	−15	+34	−17
Bottom	−38	−10	−41	+10	+25	+ 2
			A-70 Steel (Rimmed)			
Ingot 2, 1¼ In.						
Top	+57	+65	+37	+63	+116	+42
Middle	+56	+68	+31	+50	+92	+31
Bottom	+34	+47	+27	+42	+70	+29
Ingot 7, ⅝ In.						
Top	+ 8	+48	+ 8	...	...	...
Middle	+12	+40	− 6	...	...	...
Bottom	+ 4	+33	− 2	...	...	...

* Normalized plate.

and a 10-mm. ball. Three impressions were made at each location.

The average hardness for both steels was 160 and it was clear that in general the hardness decreased from top to bottom of an ingot, the difference from top to bottom being of the order of 10 points Brinell.

D. Charpy Transition Curves

Charpy impact tests were performed on samples from the same locations as the strip tensile specimens. The standard keyhole notched specimen was used in this survey (A.S.T.M. Specification E23–41T, Fig. 3, Type B), all specimens being cut with the notch perpendicular to the plate surface and the long axis of the specimen parallel to the rolling direction. Twenty-four specimens were taken from each location and four of these were tested at each of six selected temperatures. The total energy absorbed by each specimen during testing was read directly from the Charpy machine and the per cent lateral contraction below the notch and the per cent cleavage in the fracture surface were measured after testing.

The method of plotting results was the same as described for other notch tests in a previous paper on this work[10] and the transition temperatures reported in Table 6 were defined as before, as the temperature at which the curve has a value equal to the arithmetic mean of its maximum and minimum values.

In addition to the standard key-hole Charpy specimen a survey of the $1^1/_4$-in. plates was made using a double width Charpy specimen. The results of this survey are also given in Table 6.

Significant features of the results are:

1. The Charpy transition temperature according to any of the three brittleness criteria used was considerably lower for normalized plate than for as-rolled plates from the same ingot.
2. Disregarding the two normalized plates in Table 6, the transition temperatures generally decreased from the top to bottom of an ingot. This effect was most marked in the per cent cleavage transition temperatures, where the difference between top and bottom of an ingot was as high as 35° F. with the single width specimens and as high as 46° F. using double width specimens. Using the criterion of energy absorption, the change in transition temperature within an ingot was much less.
3. The transition temperature for $^5/_8$-in. plate was appreciably lower than for the corresponding $1^1/_4$-in. material.
4. Transition temperatures for A-70 rimmed steel were about 70° higher than those for A-201 killed steel.
5. Transition temperatures using fracture appearance as the criterion of brittleness were invariably higher (by as much as 50° F.) than those obtained using either of the other criteria.
6. Transition temperatures obtained with double width specimens were higher than the corresponding temperatures obtained with single width specimens.

SUMMARY

An investigation has been conducted into the variation of chemical composition and physical properties within plates rolled to two thicknesses from two heats of steel, one conforming to A.S.T.M. Specification A-201, the other to A-70. Both heats exhibited segregation and property variation generally of the type and magnitude to be expected.

The chemical composition was found to vary approximately as indicated by the extensive work of Hatfield and his collaborators.

In tension tests, the ductility was found to increase and the strength to decrease from top to bottom and from center to edge of an ingot. In Charpy tests, both single and double width, the transition temperature became lower from top to bottom of all ingots. These effects were all consistent with observed chemical segregation.

Yield points determined in the laboratory were invariably much lower than those quoted by the mill test reports for the same material.

Normalized plates had greater ductility and much lower Charpy transition temperatures than similar plates as-rolled.

Plates of $^5/_8$ in. thickness had a higher yield point, greater strength and lower transition temperatures than $1^1/_4$-in. plate.

The rimmed steel had a slightly lower grain-coarsening temperature and much higher Charpy transition temperatures than the killed steel.

ACKNOWLEDGMENT

This project was carried out jointly by the Fritz Engineering Laboratory of the Civil Engineering Department and by the Metallurgy Department of Lehigh University. It was sponsored by the Pressure Vessel Research Committee of the Welding Research Council, which is directed by William Spraragen. Walter Samans is Chairman of the Pressure Vessel Research Committee, Russel J. Love former Executive Secretary and Boniface E. Rossi current Executive Secretary. The Fabrication Division of PVRC gave technical guidance and approval of various stages of the work, under the guidance of Chairman Harry Boardman. The Materials Division of PVRC was responsible for the initial planning of the investigation and acknowledgment is due in particular to Chairman D. B. Rossheim and R. H. Caughey for assistance in this respect.

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Appendix

MILL HISTORY OF THE TWO PVRC HEATS

A. Mill History of Killed-Steel Plates, A.S.T.M. A-201

1. Open Hearth

(*a*) Material Charged:

Hot metal	327,000 lb.
Lime	32,000 lb.
Ore	72,000 lb.

(*b*) Working of Heat:

Melt analysis	1.22% C
Furnace additions	
Lime	5000 lb.
Ore	900 lb.
Si, Mn	2700 lb.
Mn (80%)	600 lb.

Time of working: 3 hr. 5 min.
Tap analysis: 0.14% C; 0.15% Mn
Tapping temperature: 3060–3080° F.
Ladle additions

Coal	100 lb.
50% Si	2000 lb.
80% Mn	700 lb.
Aluminum	500 lb.*

* Corresponding to 2.4 lb. per ton.

(*c*) Pouring:

Total weight of steel ..... 460,650 lb.
Nine big-end-up hot-topped ingots, 34 x 66 in., were poured, the weight of each being 50,450 lb.
Total pouring time (9 ingots): 45 min.
Pouring temperature
Start ..... 2910° F.
Finish ..... 2870° F.

(*d*) Ladle Analysis

Ingot No.	C	Mn	P	S	Si	Ni	Cr	Mo	Cu
2	0.16	0.54	.012	.024	0.20	0.04	0.02	0.01	0.06
4	0.15	0.53	...	...	...	...	...	...	...
9	0.16	0.52	.016	...	...	...	...	...	...

2. Rolling

(*a*) Slab Mill:

Ingots 1, 2, 3, 4, 5 and 9 were sent to the slabbing mill soaking pits.
Time from pouring to charging ..... 7 hr. 30 min.
Time in pits ..... 16 hr. 30 min.
Temperature drawn ..... 2400° F.
Slab sizes rolled

Ingots No.	Slabs from each	Slab size, in.
1, 3	4	60 x 5 1/2 x 103 1/4
2, 4, 5, 9	2	60 x 9 1/2 x 118 1/4

(*b*) Finishing Mill:

Plates were rolled 12 days after slabbing.
Heating time:
5/8-in. gage ..... 3 hr.
1 1/4-in. gage ..... 3 hr. 15 min.
Drawing temperature: 2375° F.

The finishing temperatures and test results on all as-rolled plates are given in the following Table A:

3. Heat Treatment:

Four plates of each thickness were heated to 1580° F., equalized, maintained 1 hr. and air cooled. Finishing temperatures and physical properties on these plates are shown in Table B.

Table A

Ingot No.	*Plate No.*	*Finish temp., ° F.*	*Gage, in.*	*Yield point, psi.*	*Tensile strength, psi.*	*Per cent elongation*	*Bend test*
1	7437-T	1890	5/8		63,300		
1	7438-B	1880	5/8	38,480	63,380	32.0	O.K.
1	T	1880	5/8		64,070		
3	7427-B	1820	5/8	42,520	63,950	28.2	O.K.
3	T	1820	5/8		63,270		
3	7428-B	1820	5/8	41,340	64,240	30.7	O.K.
3	T	1820	5/8		62,560		
3	7429-B	1880	5/8	40,380	63,920	32.7	O.K.
3	T	1880	5/8		63,150		
3	7430-B	1840	5/8	41,110	64,280	31.5	O.K.
3	T	1840	5/8		63,270		
4	7433-B	1880	1 1/4	38,550	62,850	29.2	O.K.
4	T	1880	1 1/4		62,320		
5	7431-T	1890	1 1/4		63,180		
5	7432-B	1890	1 1/4	37,780	63,330	29.2	O.K.
5	T	1890	1 1/4		61,330		
9	7435-B	1880	1 1/4	37,280	63,040	27.7	O.K.
9	T	1880	1 1/4		62,750		
9	7436-B	1890	1 1/4	38,920	63,050	30.0	O.K.
9	T	1890	1 1/4		63,040		

Table B

Ingot No.	*Plate No.*	*Finish temp., ° F.*	*Gage, in.*	*Yield point, psi.*	*Tensile strength, psi.*	*Per cent elongation*	*Bend test*
1	7439-B	1840	5/8	38,040	58,700	34.2	O.K.
1	T	1840	5/8		58,570		
1	7440-B	1870	5/8	39,680	61,260	34.5	O.K.
1	T	1870	5/8		60,880		
2	7442-B	1900	1 1/4	36,940	59,130	37.0	O.K.
2	T	1900	1 1/4		58,850		
4	7434-B	1900	1 1/4	37,020	60,730	36.0	O.K.
4	T	1900	1 1/4		60,330		

4. Summary

The following steel was received:

11 plates, 5/8 x 72 x 288 in. as-rolled	40,885 lb.
4 plates, 5/8 x 72 x 288 in. normalized	15,150 lb.
9 plates, 1 1/4 x 72 x 288 in. as-rolled	67,950 lb.
4 plates, 1 1/4 x 72 x 288 in. normalized	30,170 lb.
Total weight	154,155 lb.

All plates fell within the specification range of physical properties.

B. Mill History of Rimmed Steel Plates, A.S.T.M. A-70

1. Open Hearth

(*a*) Material charged:

Scrap	138,600 lb.
Pig	74,000 lb.
Lime	6,300 lb.
Limestone	4,000 lb.

(*b*) Working of heat:

Melt analysis	0.74% C
Furnace additions:	
Lime	2000 lb.
Roll scale	3000 lb.
FeMn. (80%)	1050 lb.
Spiegel	840 lb.
Fluorspar	200 lb.
Time of working: 2 hr. 3 min.	
Tap analysis: 0.14% C; 16.00% FeO in slag	
Tapping temperatures	2980° F.
Ladle additions:	
Coal	280 lb.
Aluminum	10 lb.*
CaO	750 lb.

(*c*) Pouring: Total weight of steel 187,000 lb.

8 bottom-poured ingots 34 x 14 in. were poured to a depth of 46 in., each weighing 5050 lb.

6 bottom-poured ingots 48 x 17 in. were poured to a depth of 55 1/2 in., each weighing 10,500 lb.

Two groups of ingots for other orders were also poured from this heat.

Pouring time:	
34 x 14-in. group	5.40 min.
48 x 17 in. group	7.83 min.
Total	26 min.
Pouring temperature:	
34 x 14-in. group	2875° F.
48 x 17-in. group	2860° F.

(*d*) Ladle Analysis:

C	Mn	P	S	Ni	Cr	Cu
0.25	0.36	0.016	0.031	0.15	0.058	0.19

2. Rolling

(*a*) Slab Mill:

6 small and 6 large ingots were conditioned and rolled.

Time from pouring to charging in pits	42/44 hr.
Soaking:	
Small ingots	7 hr. 20 min. at 2350° F.
Large ingots	11 hr. 25 min. at 2370° F.
Slab thickness:	
Small	3.40 in.
Large	5.75 in.
Slab temperature:	
Small	2000° F.
Large	1980° F.

(*b*) Finishing Mill:

All slabs ran straight through the finish mill without intermediate heating.

Individual finishing temperatures are given in the following table together with the mill test results:

Ingot No.	*Plate gage, in.*	*Finish temp., ° F.*	*Yield Point, psi.*	*Tensile Strength, psi.*	*Per cent elongation*
1	1 1/4	2000		58,800	
			39,100	59,700	29.5
2	1 1/4	2000		60,200	
			39,600	59,700	30.0
3	1 1/4	2000		59,100	
			38,900	58,600	32.0
4	1 1/4	2000		59,400	
			38,500	59,000	29.5
7	5/8	2000		55,400	
			39,600	62,800	27.5
9	5/8	2000		63,800	
			38,600	63,300	27.0
11	5/8	2000		63,800	
			37,300	64,500	27.5
12	5/8	2000		62,700	
			39,100	63,000	27.5

All bend tests satisfactory.

3. Heat Treatment

Two plates of each thickness were heated to 1630° F., equalized, held 1 hr. per inch of section and air cooled. Finishing temperatures and test results on these plates were as follows:

Ingot No.	*Plate gage, in.*	*Finish temp., ° F.*	*Yield point, psi.*	*Tensile Strength, psi.*	*Per cent elongation*
5	1 1/4	2000		61,200	
			38,300	60,500	28.5
6	1 1/4	1980		61,000	
			38,700	60,200	27.5
8	5/8	2010		63,200	
			39,900	64,400	27.5
10	5/8	2010		63,400	
			38,800	62,300	27.0

All bend tests satisfactory.

4. Summary

The rimmed steel received was comprised of the following:

4 plates, 5/8 x 72 x 288 in., as-rolled	15,055 lb.
2 plates, 5/8 x 72 x 288 in. normalized	7,530 lb.
4 plates, 1 1/4 x 72 x 288 in., as-rolled	29,970 lb.
2 plates, 1 1/4 x 72 x 288 in. normalized	14,980 lb.
Total weight	67,535 lb.

All plates fell within the specification range of physical properties.

* Corresponding to 0.1 lb. per ton.

The Welding of Pure Molybdenum

Results obtained in welding pure molybdenum and the necessity of proper welding precautions are presented

by H. J. Nichols, K. B. Young and M. J. Nolan

Abstract

Pure molybdenum, for many years a laboratory curiosity, is now becoming of increasing importance for structural uses. Its unique properties are such that newly developing fields of science would be handicapped if it were not available. This paper presents some preliminary results obtained in welding molybdenum of 99.9% purity and calls attention to the necessity of the proper welding precautions. The pseudowelds obtained in molybdenum with common welding processes are quite brittle; reasons for this are advanced.

INTRODUCTION

UNTIL recently, the production of high-purity, low-cost, ductile molybdenum by common extractive metallurgical methods was defeated by the high melting point of the metal and by its high affinity for oxygen at elevated temperatures. The development of the vacuum arc method, in 1946,[1] using pressed and sintered powdered molybdenum electrodes, made possible the production of fairly large sheets and shapes. It was inevitable, with sheet available, that a demand for fabricated articles should soon follow. The electronic-tube industry[2] has pioneered in the field of production and fabrication, but there is little in the literature to provide assistance to those in the welding industry confronted for the first time with the necessity of welding sheet molybdenum.

The authors were requested to fabricate crucibles 3 x 1 in. I.D. from 0.030-in. sheet, to contain molten salts at 1800° C. in vacuum. The sheet was sheared to the required part sizes and in shearing it was noted that in many cases the sheared edges cracked parallel to the surfaces in a manner very reminiscent of laminated sheet steel. Fabrication continued by bending to the required form, followed by gas, atomic hydrogen or inert-gas arc welding. In at least some cases, attempts to bend the sheet to form the cylindrical body of the crucible resulted in cracks running at an approximate angle of 45° to the direction of rolling. Where bending was successfully accomplished, the welds in every case were extremely brittle; in many cases they exhibited cracks at an angle of 45° to the direction of bending.

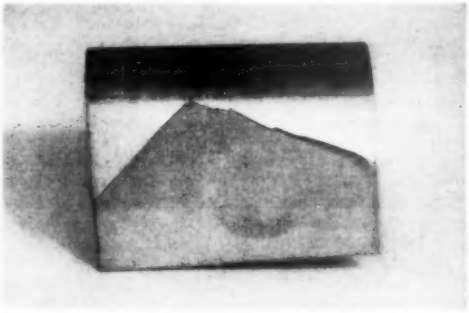

Fig. 1 Sheet Material Partially Bent to Form Crucible Barrel

The 45° crack occurred first and spread in a ragged manner. Actual size

It was deemed desirable to subject the material to a thorough metallurgical examination to determine the cause of the difficulties encountered in crucible fabrication. The results of this investigation are reported herein.

PROCEDURE

1. A sample of sheet which cracked in bending was photographed (see Fig. 1).

2. Samples from this piece, longitudinal and transverse to the direction of rolling, were mounted, polished, etched and examined under a microscope. Figures 2 and 3 show the longitudinal and transverse microstructures, respectively.

3. A sample transverse to a sheared edge was mounted, polished and etched. Figure 4 shows the defect at the sheared edge.

4. Hardness tests were made on as-received material, using a Vickers machine and a 10-kg. load. An average of seven impressions was 274 V.P.N.

5. The as-received sheet, purchased to 99.9% purity

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Fig. 2 Longitudinal Microstructure of Molybdenum Sheet
Etched in 10-gm. ferric chloride, 30 cc. concentrated HCl and 120 cc. H_2O. 500 ×

was subjected to a spectrographic analysis, with the following results: traces of Fe, Cr, Sn, Bi and Si.

6. The butt welds, used to join the edges of the barrel of the crucibles, were attempted with oxyacetylene, atomic hydrogen and inert-gas arc welding. In each case, a sheared strip of the as-received material was used as a filler rod. In an attempt to provide protection from atmospheric oxygen, the material was lightly jigged and placed in the bottom of an open-mouthed vessel. Argon under 5 lb. pressure, flowing at a rate of 7 litres per minute, was led into the vessel and an asbestos cover was placed over the open end. The cover had a hole cut to the shape of the weld area so that all escaping argon, after the initial air had been displaced, exhausted to the atmosphere through the weld area.

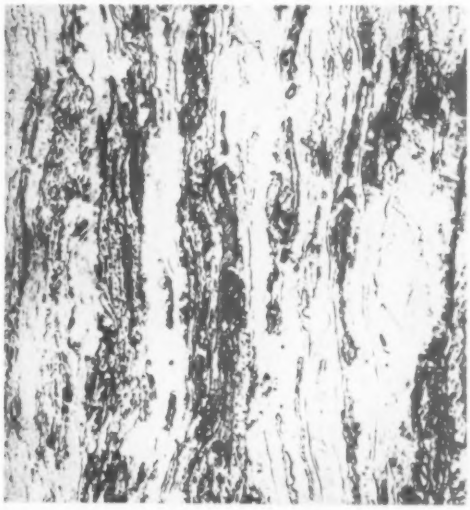

Fig. 3 Transverse Microstructure of Molybdenum Sheet
Same etchant as in Fig. 2. 500 ×

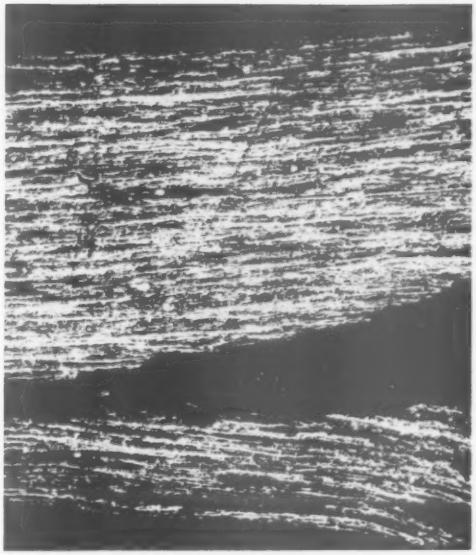

Fig. 4 Fracture Typical of Sheared Edges Giving Laminated Appearance
Same etchant as in Fig. 2. 100 ×

As reported above, all the welds so obtained were brittle; many cracked, the cracks extending out into the parent metal (see Fig. 5). Transverse samples through two cracked welds (atomic hydrogen and inert-gas arc welded) were mounted, polished and examined under the microscope. Figure 6 shows the macrostructure characteristic of all welds produced. Figure 7 shows the microstructure typical of all welds.

DISCUSSION

The sensitivity of molybdenum sheet to cracking at an angle of 45° to the direction of rolling is typical of material that has been cross-rolled.[3] X-ray diffraction patterns have shown that cross-rolling orients the crystals approximately to the completely preferred state, that is, such that the (100) planes lie at right angles to

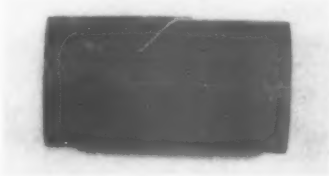

Fig. 5 Typical 45° Crack Beginning in a Brittle Weld
Note irregular path of crack after initial 45° crack occurred. Natural size

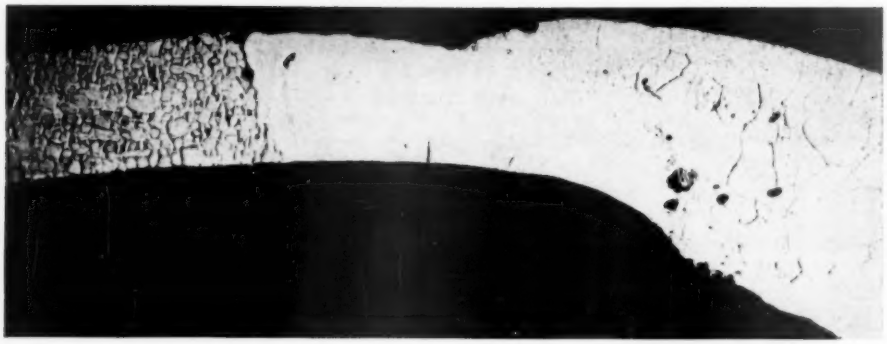

Fig. 6 Macrophotograph of Typical Inert-Gas Arc Weld

Extreme left, recrystallized metal; extreme right, weld metal. The center area is heat-affected zone, in which no grain boundaries could be detected. 90 ×

the sheet surface and 45° to the direction of rolling. Since these planes are the cleavage planes in molybdenum this fact seems to account for the 45° brittleness. That the material used in the experiments reported herein has been cross-rolled is shown by Figs. 2 and 3, and therefore its tendency to cracking is not surprising.

The laminated appearance of the sheet edges after shearing has been found to be due to cracking parallel to the sheet surfaces. The cause for this cracking is not definitely known but it is believed to be due to the low ductility of the material. The initial cutting action of the shearing blade proceeds without difficulty but the cracking was observed when shearing occurred. Further evidence of low ductility in all directions to rolling was observed when attempts were made to both cold spin and hot spin (1500° F.) the required retorts. The attempts at cold spinning resulted in fracture of the material after a deflection in the order of 4–6 mm. The hot-spinning attempt ended in material rupture after bending to approximately 45°. It will be noted from Fig. 8 that uniform deflection was not obtained in hot spinning, the material folding into five pleats. Such low ductility is widely different from some of the published data.[3, 4]

Microscopic examination of cracked welds revealed some peculiarities not encountered in the commoner metals. As shown in Fig. 6, there is no trace of grain boundaries in what might be referred to as the heat-affected zones of the welds. Examination of this area up to a magnification of × 1000 failed to reveal grain boundaries. The area just beyond this shows a normal equiaxed grain common to metals heated above their recrystallization temperatures. For this particular molybdenum sheet the grain growth germination temperature must have a critical (lower) limit, since its end is marked by a sharp line. Above this temperature, grain growth has proceeded to what is apparently one grain in the area between the weld metal and the recrystallized metal.

The cause of cracked and brittle welds is evident from Fig. 7. In every case the large weld grains are totally enclosed in an envelope of an unknown constituent.

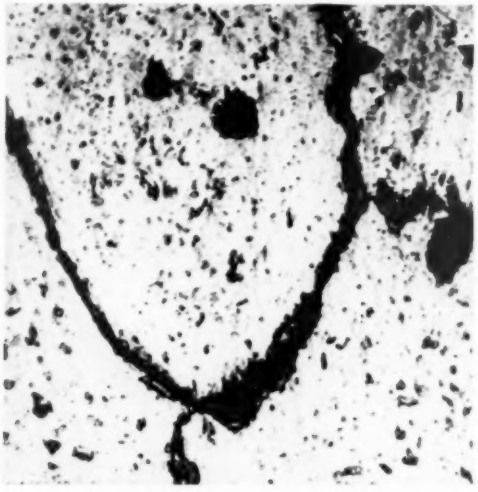

Fig. 7 Typical Structure of Weld Metal

Note nonmetallic film in grain boundaries and similar material within the grains. The mauve coloration under white light is suggestive of Mo_2O_5. Etched as in Fig. 2. 1000 ×

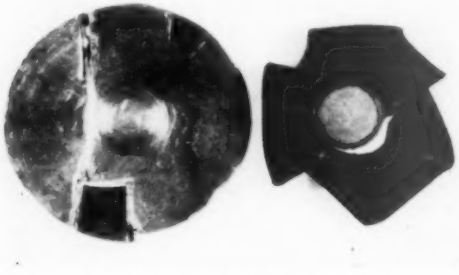

Fig. 8 Hot and Cold Spinning Tests

Left: Cold spinning test. Material fractured badly after bending 4–6 mm. Right: Hot spinning test. Material fractured after bending 45°. Note folding rather than uniform deflection. 40% actual size

This intergranular phase appears to be nonmetallic and is believed to be an oxide of molybdenum. Apparently the phase is rejected to the crystal boundaries and there concentrates during solidification. It is reported[1] that differences in oxygen content between workable and unworkable molybdenum are in the order of 0.0025%; yet when this small amount appears at grain boundaries in the form of oxide the metal is rendered brittle.

Unfortunately, the production process and the rolling procedure employed on the material used in these experiments are unknown. The low ductility of the as-received material has been commented upon above. Low ductility may result from small amounts of oxygen or, as stated by Marden and Wroughton,[4] from improper rolling procedures. A thorough examination of the as-received material failed to reveal any trace of an intergranular phase. While this cannot be construed as complete evidence of the absence of an embrittling amount of oxygen, it does give some basis for belief that the intergranular phase appears as a result of welding.

The source of the oxygen which causes brittleness in welds made by the oxyacetylene and atomic hydrogen processes probably lies in the products of combustion of the gases together with atmospheric oxygen drawn into the welding area by turbulent gas conditions during welding. In the inert-gas arc-welding processes, small traces of water vapor, or hydrocarbons together with atmospheric oxygen, may be the oxygen source. In any event, these experiments show that if pseudowelds are to be avoided, gas shielding must be given very careful consideration. It is, then, apparent that molybdenum sheet of this thickness cannot be welded by the processes used in these experiments unless virtually complete protection from atmospheric oxygen is provided. Such complete protection is both difficult to obtain and expensive and points to the desirability of such welding processes as resistance spot welding. The rapid thermal cycle and high electrode pressures of resistance welding would both tend to reduce oxygen enrichment of the molybdenum.

It is unfortunate that there is no known heat treatment that could be used to restore ductility to brittle welds. A survey of the literature reveals that only remelting, deoxidation, casting and working would be effective. This is to be expected from the nonmetallic nature of the intergranular phase causing weld embrittlement.

Working and heat treatment impart high tensile strength and good ductility to the metal, which inherently is moderately hard and brittle. Recrystallization temperatures of molybdenum depend upon the amount of working, and therfore annealing practices vary with the procedures used. For this reason, neither preheating before welding, nor stress relief or annealing after welding, can be recommended. Molybdenum articles fabricated from sheet stock should be designed with generous safety factors to compensate for the uncertainties associated with their manufacture.

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Research Fellowships

THE Welding Research Council, since its very inception, has appreciated the value and importance of fundamental research which has for its concept the understanding of "why" certain phenomena takes place. In organizing its projects and Project Committees which guide the work, the Council has always sought to include a reasonable representation from the scientific group. On the other hand, Project Committees are generally under considerable pressure to produce results, which can be used by engineers or by code-making bodies or procedure committees, within the shortest possible space of time. In other words, these committees seek the quickest answer of how to do a certain job, and are not too concerned with the "why." Unfortunately, however, this method of operation does not always yield optimum conditions nor is it always possible to utilize the results beyond the range of experimentation unless some additional tests are made. In a measure, a great deal of the work of the Project Committees can be looked upon as an engineering type of research.

The type of work referred to above and also that carried out by most of our industrial laboratories utilizes as raw material the scientific facts and basic information developed by other experimenters, perhaps for totally different purposes. This has indicated to the Council on many occasions the need for developing new information in the underlying sciences related to welding which can be later used by the Project Committees and by industrial research laboratories.

Probably one of the most successful method of conducting research is to form a hypothesis or a skeleton theory of certain phenomena in connection with the field of operation. Research work is then planned to either prove or disprove the hypothesis, or more likely, to bring about necessary modifications and extensions

in the hypothesis This type of research requires a careful groping of the way rather than the carrying out of fixed programs laid out in advance.

This type of research necessitates a careful knowledge of what has been done in the past. Recognizing the needs for this type of information, the first five or six years of the Council operations were devoted very largely to reviewing the world's literature on welding research and closely allied fields, and condensing such information so that it could be utilized by research men and engineers. No attempt was made in these reviews to form hypotheses or skeleton theories. The Council is planning to resume this literature work but it hopes to go somewhat further in critically analyzing the results, than was possible in the earlier literature reviews.

In order to stimulate the more fundamental type of research, the Council organized a University Research Committee to foster and expedite research of this type in the universities without the immediate objective of utilitarian results. Unfortunately, it was not possible to make available any large sums of money for this purpose so that the only help that could be rendered to the University Committee was provision once a year for a conference and occasionally small grants-in-aid to selected universities for specific pieces of research. To extend this type of endeavor and to administer the work in a more businesslike fashion, the Welding Research Council has decided to create four Fellowships, each involving a total expenditure of $3500, to be known in the name of the sponsor company. In other words, if a company contributed the $3500 for a Fellowship, it would be known in the name of that company. The work would be handled by the University Research Committee who will create a special Fellowship Board to be composed of nine people, including five outstanding scientists and one representative each from the sponsor companies. Careful rules and regulations will be promulgated to assure the selection of the highest type of Fellows and the necessary scientific guidance by appropriate members of the faculty of the university concerned. Suggested problems are being compiled to serve as a guide to the type of problems which the Fellowship Board would consider favorably. These typical problems are not meant, however, to be restrictive, as the exact problem would depend upon the interest of the Fellow and the guiding professor in the university.

In order to permit the staff and the officers of the Council to devote the necessary time to the guidance of this new project, the number of Fellowships has been limited to four. Several companies have already indicated interest in this plan and it is hoped that the project can be launched very shortly. Anyone having an interest in these proposals should communicate with the Director of the Welding Research Council, 29 W. 39th St., New York 18, N. Y.

Welding Research News

In order to render a new type of service to the Research Workers and Subscribers of the Welding Research Council, a new publication has been launched under the title *Welding Research News*. This publication will be issued bi-monthly. Each issue summarizes the research progress made during a two-month period, in terms which will attract the attention of both the research worker and the executive engineer.

In this way Subscribers will obtain a high-spot bi-monthly review of currently completed researches. The first News Letter was issued in January 1949 and covered a bi-monthly period starting with January 1948. In order to bring these reviews to date, the News Letter will be issued monthly for the time being. Four issues have already been distributed and have attracted widespread attention. Its publication is in addition to the regular publications of the Council which, among other things, include the following:

1. A monthly *Welding Research Supplement* which contains the completed reports of the Council projects and those of affiliated organizations and companies cooperating in specific portions of the program.
2. A monthly mimeographed *Progress Reports Series* which gives progress on researches under way, but not yet completed. This series also includes translations of important foreign articles, proposed programs of research, and items of general interest to the Subscribers and Research Workers of the Council.
3. A *Bulletin Series*. This, too, is a new publication series of the Council which includes reprints of important papers presented before other Societies than the American Welding Society. Three Bulletins have been issued and two additional ones are in progress.

Anyone interested in any of these publications should communicate with the Director of the Welding Research Council, 29 W. 39th St., New York 18, N. Y.

Arc welding by the inert-gas-shielded method using Everdur 1010 Rod. Dished Everdur 1010 head is being joined to storage heater shell made of welded Everdur 1010 hot rolled-and-annealed tank plate.

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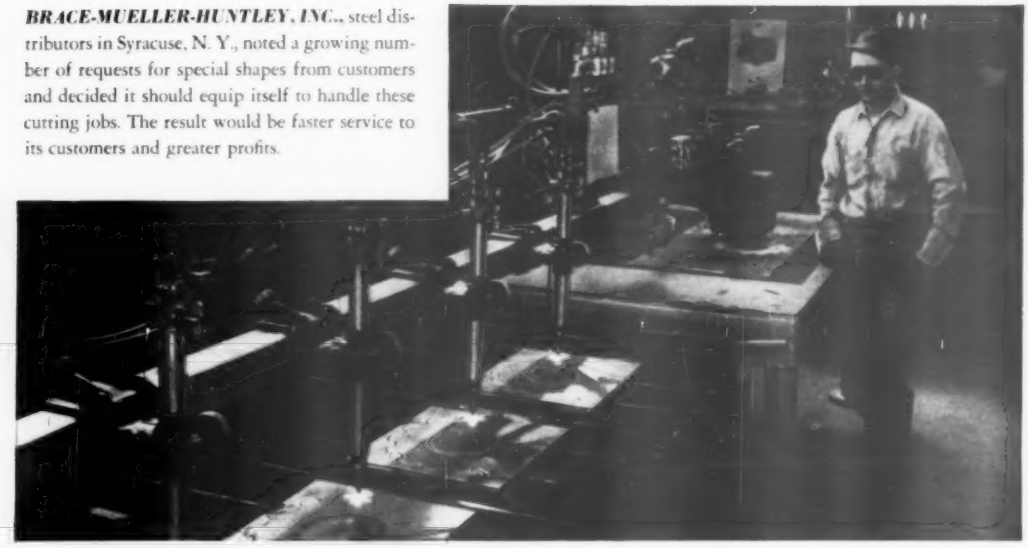
Steel warehouse finds machine gas cutting helps fill special orders...faster—at less cost

BRACE-MUELLER-HUNTLEY, INC., steel distributors in Syracuse, N. Y., noted a growing number of requests for special shapes from customers and decided it should equip itself to handle these cutting jobs. The result would be faster service to its customers and greater profits.



William Burkhardt, Airco Representative, was called in and he recommended machine gas cutting with an Airco No. 6B Oxygraph equipped with a four torch setup and an electronic tracing device.

The apparatus was quickly installed and put into operation. One-day service was offered to customers requiring intricate as well as ordinary shapes.

The executives of Brace-Mueller-Huntley, Inc., stated that the Oxygraph with the electronic tracing device enabled them to make additional profits and also to handle a wide variety of cutting jobs quickly and easily.

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